

AD-A036 841

WASHINGTON UNIV SEATTLE APPLIED PHYSICS LAB
INTERFERENCE SEALS AND CONNECTORS FOR UNDERSEA
JUL 76 J PARADIS

F/G 13/10
ELECTRICAL APPLI--ETC(U)
N00017-74-C-1208

UNCLASSIFIED

NL

1 OF 4
AD
A036 841



Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)

Chesapeake Division, Naval Facilities Engineering
Command, Bldg. 57, Washington Navy Yard
Washington, D.C. 20374 ATTN: FPO-1ED13

2a. REPORT SECURITY CLASSIFICATION

UNCLASSIFIED

2b. GROUP

3. REPORT TITLE

Reference Manual on Interference Seals and Connectors for Undersea Electrical
Applications

9. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Reference Manual,

5. AUTHOR (First name, middle initial, last name)

James Paradis

12 317p.

11. REPORT DATE

July 1976

7a. TOTAL NO. OF PAGES

Approx. 200

7b. NO. OF REFS

6. CONTRACT OR GRANT NO.

b. PROJECT NO

c.

d.

9a. ORIGINATOR'S REPORT NUMBER(S)

9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT

Approved for General Release - Distribution Unlimited

11. SUPPLEMENTARY NOTES

12. SPONSORING MILITARY ACTIVITY

13. ABSTRACT

This manual investigates the factors involved in the theory and design of underwater cable seals or packings of the interference type. It established standards for the sizes, proportions and materials for component parts, and for assemblies of seals with both single and multiple packings. It classifies commercially available underwater electrical connector series according to their material composition, and describes them through the use of a standard matrix which lists several critical design features. It supplies manufacturers' addresses and a list of significant users of their underwater electrical connectors. Additional organizations with special underwater electrical connector design capabilities are also listed. The manual also identifies and describes the most common failure modes in submerged electrical connectors and describes practiced methods of preventing failures.

031 700

DD FORM 1473

1 NOV 65

(PAGE 1)

PLATE NO. 21856

S/N 0102-014-6600

Security Classification

4/3

KEY WORDS

14.	KEY WORDS	LINK A		LINK B		LINK C	
		ROLE	WT	ROLE	WT	ROLE	WT

(1)
B.S.

**Reference Manual
on
Interference Seals
and
Connectors
for
Undersea Electrical
Applications**

NAVAL FACILITIES ENGINEERING COMMAND
Chesapeake Division, Washington Navy Yard
Washington, D.C. 20374



Prepared by

Applied Physics Laboratory
University of Washington
Seattle, Washington

JULY 1976

DISTRIBUTION STATEMENT A

Approved for public release;
Distribution Unlimited

ABSTRACT

This manual investigates the factors involved in the theory and design of underwater cable seals or packings of the interference type. It establishes standards for the sizes, proportions and materials for component parts, and for assemblies of seals with both single and multiple packings. It classifies commercially available underwater electrical connector series according to their material composition, and describes them through the use of a standard matrix which lists several critical design features. It supplies manufacturers' addresses and a list of significant users of their underwater electrical connectors. Additional organizations with special underwater electrical connector design capabilities are also listed. The manual also identifies and describes the most common failure modes in submerged electrical connectors and describes practiced methods of preventing failures. Included under a separate binding is a Master Catalogue containing the available catalogues of known connector companies. The Master Catalogue is interreferenced with the connector matrices and company listings of the manual.

This Master Catalogue is not available from DDC. If required, direct request to: Chesapeake Division, of the Naval Facilities Engineering Command.

ACCESSION for	
NTIS	Write Section <input checked="" type="checkbox"/>
DDC	Buff Section <input type="checkbox"/>
UNANNOUNCED	<input type="checkbox"/>
JUSTIFICATION	
BY	
DISTRIBUTION/AVAILABILITY CODES	
Dist.	AVAIL. and/or SPECIAL
A	

PREFACE

The Reference Manual on Interference Seals and Connectors for Undersea Electrical Applications was prepared in July 1976, for the Naval Facilities Engineering Command, Chesapeake Division, Washington Navy Yard, Washington, D.C. It was compiled under Contract Number N00017-74-C-1208 by the Applied Physics Laboratory, University of Washington, with the technical assistance of James Morrison and Colin Sandwith, under the general editorship of James Paradis.

CONTENTS

<u>Section</u>	<u>Title</u>	<u>Page</u>
	Abstract	iii
	Preface	iv
	Table of Contents	v
	Introduction	vii
1	AN INVESTIGATION OF INTERFERENCE CABLE SEALS	1-1
1.1	Summary	1-1
1.1.1	Conclusions of the Investigation	1-1
1.1.2	Design Suggestions for Interference Cable Glands	1-2
1.1.3	Plans for Further Investigation	1-3
1.2	Introduction	1-3
1.2.1	Typical Cable Glands	1-4
1.3	An Analysis of Sealing Action	1-5
1.3.1	Stress-Strain Relationships in a Tri-Axial Stress System	1-5
1.3.2	Mechanical Properties of Packing Materials	1-7
1.3.3	Gland Behavior	1-8
1.4	Interference (Automatic) Seals	1-10
1.4.1	Interference Seal Behavior	1-10
1.5	Experimental Investigation of Interference Seals	1-13
1.5.1	Preliminary Testing	1-13
1.5.2	Tests Using a Brass Pressure Unit	1-15
1.5.3	Tests Using a Transparent Pressure Chamber	1-18
1.5.4	An Experimental Interference Seal	1-26
1.6	Cable Seal Design	1-27
1.7	References	1-28
2	A STANDARD FOR SIMPLE INTERFERENCE CABLE SEALS	2-1
2.1	Introduction	2-1
2.1.1	Scope	2-1
2.1.2	Principle of Operation	2-2
2.2	General Description	2-2
2.3	Assembly Procedure	2-4
2.4	Design Specifications--Materials and Dimensions	2-5
2.4.1	Housing and Retaining Ring	2-6
2.4.2	Packing	2-8
2.4.3	Retaining Washer (Seal W/O Boot)	2-10
2.4.4	Retaining Washer (Seal with Boot)	2-12
2.4.5	Boot (Optional)	2-14
2.5	References	2-16
3	STANDARD FOR AN INTERFERENCE CABLE SEAL AND REPEATER HOUSING ASSEMBLY	3-1
3.1	Introduction	3-1
3.1.1	Scope	3-2
3.1.2	Principle of Operation	3-2
3.1.2.1	Seal Support	3-3
3.1.2.2	Additional Design Possibilities	3-4

<u>Section</u>	<u>Title</u>	<u>Page</u>
3.2	Cable Specifications and Sources	3-5
3.2.1	Cable Splicing	3-6
3.3	General Description	3-10
3.3.1	Parts List	3-14
3.4	Assembly Procedure	3-15
3.5	Design Specifications--Materials and Dimensions	3-24
4	COMMERCIAL OFF-THE-SHELF UNDERWATER ELECTRICAL CONNECTORS-- A CLASSIFICATION WITH DESCRIPTIVE MATRICES	4-1
4.1	Introduction	4-1
4.1.1	Scope	4-3
4.2	Critical Design Factors	4-4
4.2.1	The Housing	4-6
4.2.2	Electrical Contacts	4-7
4.2.3	Electrical Insulation	4-8
4.2.4	Cable to Plug/Receptacle Seals and Mating Seals	4-8
4.2.5	Strength Member Termination and Strain Relief	4-9
4.3	Connector Classification	4-10
4.3.1	Molded Rubber Assemblies (RM)	4-10
4.3.2	Molded Plastic Assemblies (PM)	4-11
4.3.3	Metal Shell Assemblies (MS)	4-12
4.3.4	Pressure-balanced Oil-filled Assemblies (PBOF)	4-14
4.3.5	Underwater Mateable Assemblies (UM)	4-14
4.4	Connector Matrices	4-15
4.4.1	Matrix Disclaimer	4-15
4.5	References	4-16
5	GUIDE TO UNDERWATER ELECTRICAL CONNECTOR MANUFACTURERS-- STANDARD AND CUSTOM DESIGNS	5-1
5.1	Introduction	5-1
5.1.1	Scope	5-1
5.2	Combined Custom and Standard Line Manufacturers	5-2
5.3	Custom Underwater Connector Manufacturers	5-20
6	REFERENCE SECTION	6-1
6.1	Failure Analysis and Prevention	6-1
6.1.1	Introduction	6-1
6.1.2	Performance/Failure Analyses: Some Results and Recommendations	6-3
6.1.3	Failure Mode Analysis	6-8
6.1.4	Quality Assurance: Quality Control and Certification Guidelines	6-24
6.1.5	Performance/Failure Analysis Plan	6-39
6.1.6	Directions for Future Research	6-43
6.1.7	References	6-44
6.2	Pertinent Military Specifications	6-45
6.3	Bibliographies on Connector Technology and Related Subjects	6-49

-Z-12-

INTRODUCTION

CONTENT

The information in this manual is divided into two general classifications--interference seal theory and design (Sections 1-3), and commercial underwater electrical connector descriptions, sources, and failure analyses (Sections 4-6). The purpose of the manual is to provide a reference on underwater connectors and seals for use by engineers in selecting or designing an appropriate connector or interference seal for a particular underwater application. The manual deals primarily with interference seals and electrical connectors intended for long-term underwater use.

Section 1 examines the mechanics of cable seals or glands with flexible packings which are designed for use at ocean depths of up to 1,000 feet, and is based on studies made by James Morrison in 1954 that led to the design of the Morrison, or interference, seal. The purpose of such seals is to prevent leakage at the point of entry of electrical cables into undersea vessels and bulkheads.

Section 2 provides a design standard for the construction of simple interference seals. It establishes recommended sizes, proportions, and materials for seals utilizing single rubber packings for use at depths up to 1,000 feet.

Section 3 establishes dimensions and materials for the advanced interference seal design called the Cable Seal and Repeater Housing Assembly. This unit is designed to seal a number of standard coaxial range cables for a duration of 20 years and at depths of up to 7,000 feet. It is also used as a field splice.

Section 4 examines the commercial/underwater electrical connector market. It discusses various factors that must be taken into consideration in selecting a connector from a commercial manufacturer, and considers critical design factors in connector technology. This section classifies commercial connectors according to material composition. The classes of connectors include: Rubber Molded (RM), Plastic Molded (PM), Metal Shell (MS), Pressure-Balanced Oil-Filled (PBOF), Underwater Mates (UM), and Miscellaneous Connectors (Misc.). At the end of Section 4 is a series of matrices, organized into units according to the classification just described, that provides a material, mechanical, electrical and environmental profile on representative connector series made by commercial connector manufacturers. This section is inter-referenced with the Master Catalogue that accompanies this manual.

Section 5 lists approximately 40 organizations that are presently involved in the commercial production of underwater electrical connectors. Many of these firms produce both standard and custom lines of connectors. This section is also interreferenced with the Master Catalogue that accompanies this manual.

Section 6 is a reference section, but is also devoted to failure analysis and failure prevention for connectors and interference seals. It contains a number of detailed considerations of connector performance and failure rationales, failure mode analyses, quality assurance tests, and a performance and failure analysis plan.

FORMAT

The manual is organized into six sections, each of which is meant to be an independent reference unit. Section dividers are provided for quick reference.

The Master Catalogue is a collection of currently available supplier literature and catalogues on electrical connectors, and is meant to be used in conjunction with the manual itself. It is organized alphabetically by manufacturer and is interreferenced with Sections 4 and 5 of the manual.

INFORMATION SOURCES

Technical information contained in this manual has been supplied by the Applied Physics Laboratory staff, and by commercial producers of interference seals. Sections 1, 2, 3, and 6 contain information and specifications that have, for the most part, been generated through 20 years of experience at APL in the design and use of interference seals, also known as Morrison seals. Some of the information on service experience with submerged electrical connectors used to compose Section 6.1.2 was supplied by the Naval Torpedo Station, Keyport, Washington. The information on commercial organizations in Sections 4 and 5 was obtained through product research, including an extensive mail survey of all organizations that were identified as producers of underwater electrical connectors. The Applied Physics Laboratory has neither validated nor investigated the claims of manufacturers. The primary purpose of Sections 4 and 5 is to identify the connector products on the commercial market today and to give some indication of the applications for which they are intended.

UPDATING THIS MANUAL

The information contained in Sections 4 and 5 is highly variable and should be updated periodically, preferably every two years. New matrices should be added and new catalogues obtained from connector manufacturers and added to the Master Catalogue. Addresses for connector manufacturers listed in Section 5 should be checked periodically, and new manufacturers added as they are brought to the user's attention.

Section 1

TABLE OF CONTENTS

<u>Section</u>	<u>Title</u>	<u>Page</u>
1.1	Summary	1-1
1.1.1	Conclusions of the Investigation	1-1
1.1.2	Design Suggestions for Interference Cable Glands	1-2
1.1.3	Plans for Further Investigation	1-3
1.2	Introduction	1-3
1.2.1	Typical Cable Glands	1-4
1.3	An Analysis of Sealing Action	1-5
1.3.1	Stress-Strain Relationships in a Tri-axial Stress System	1-5
1.3.2	Mechanical Properties of Packing Materials	1-7
1.3.3	Gland Behavior	1-8
1.4	Interference (Automatic) Seals	1-10
1.4.1	Interference Seal Behavior	1-10
1.5	Experimental Investigation of Interference Seals	1-13
1.5.1	Preliminary Testing	1-13
1.5.2	Tests Using a Brass Pressure Unit	1-15
1.5.3	Tests Using a Transparent Pressure Chamber	1-18
1.5.4	An Experimental Interference Seal	1-26
1.6	Cable Seal Design	1-27
1.7	References	1-28

Section 1

LIST OF FIGURES AND TABLES

<u>Figure</u>	<u>Title</u>	<u>Page</u>
1-1	Typical Compression Type Cable Glands	1-4
1-2	The Tri-axial Stress System of the Seal	1-5
1-3	Effect of Tightening a Compression Cable Gland	1-8
1-4	A Typical O-ring Installation	1-11
1-5	Action of a Rubber Interference Seal Under Fluid Pressure	1-12
1-6	Modified Cable Junction Chamber	1-14
1-7	Brass Pressure Test Unit	1-15
1-8	Packing Test Unit with Transparent Pressure Chamber	1-18
1-9	Parts of Transparent Tube Assembly	1-19
1-10	Parts of Test Unit	1-20
1-11	Testing Arrangement for Transparent Test Unit	1-20
1-12	Pressure Distribution on Seal Face	1-23
1-13	Effect of Axial Tightening on an Interference Packing	1-25
1-14	An Experimental Interference Seal	1-27

<u>Table</u>	<u>Title</u>	<u>Page</u>
1-1	Values of Fluid Pressure (P_f) and Seal Face Pressure (P_s) on an Interference Cable Gland with No Axial Tightening	1-23
1-2	Values of Fluid Pressure (P_f) and Seal Face Pressure (P_s) on an Interference Cable Gland with Initial Axial Tightening	1-25

Section I

AN INVESTIGATION OF INTERFERENCE CABLE SEALS

1.1 Summary

The bulk of this 1954 investigation is devoted to the fundamental mechanics of cable seals or glands employing flexible packings at ocean depths of up to 1000 feet or approximately 500 psi. The principles set forth in the following study, completed in 1954 by Professor James Morrison at the Applied Physics Laboratory of the University of Washington, led to the original design of the Interference Cable Seal, also known as the Morrison Seal. This sealing technique is now in wide use.

1.1.1 CONCLUSIONS OF THE INVESTIGATION

Morrison drew the following conclusions from his investigation in support of interference or automatic cable seals over other conventional cable glands:

1. To obtain a dependable static seal against fluid leakage it is necessary that the seal surfaces be held together with a pressure in excess of the fluid pressure to be contained.
2. The mechanical properties of rubber make it a highly desirable packing material for cable seals.
3. The use of radial interference between packing and cable and between packing and gland wall establishes an automatic sealing action by the rubber packing; whereas if gland and cable clearance are provided in the packing, the sealing action depends upon the correct subsequent tightening of the gland nut.
4. The effectiveness of conventional cable glands is improved by substituting interference packings of rectangular cross section.

1.1.2 DESIGN SUGGESTIONS FOR INTERFERENCE CABLE GLANDS

The following general recommendations are offered for the design of interference cable seals (for more detailed specifications, see Section 2 of this manual, "A Standard for Simple Interference Cable Seals"):

1. The packing should be natural or synthetic rubber compound of 35 ± 5 durometer hardness. Compounds with maximum resistance to permanent set are most desirable.
2. Where possible, the packing should be molded. Otherwise, the inner and outer circumferential surfaces should be made smooth, as by finishing with fine emery cloth.
3. The axial length of the packing should be at least one cable diameter.
4. The hole through the packing should be from 0.5 to 0.7 times the cable diameter, depending upon the cable construction. Less interference is required with a firm coaxial cable than with a softer twisted type.
5. The inside diameter of the gland body should be from two to three times the cable diameter with a surface of 32 machine finish or better.
6. The outside diameter of the packing should be from $1/64$ to $1/32$ inch larger than the gland body diameter, before assembly.
7. Bushings or washers used at the ends of the packing should fit the cable diameter as closely as possible without interference.
8. The cable should be supported against sharp bends for at least one cable diameter outside the packing by a close-fitting bushing with the corners rounded to prevent cable damage.
9. That portion of the cable in contact with the packing should be free of any surface defects or sharp indentations.
10. Where a snap ring is used to retain the parts, allowance should be made for the increase of axial length of the packing when assembled. This may be done by assuming a constant volume for the packing and neglecting deformation of the cable.
11. Leakage is less likely where the "downstream" end face of the packing is supported directly by the gland body than where a separate washer or bushing is used between these surfaces.

1.1.3 PLANS FOR FURTHER INVESTIGATION

Morrison recommended that continuation of his 1954 study include further investigation of the following topics:

1. Theoretical and experimental investigation of durability in interference and compression type cable glands.
2. Investigation of the effects of tensile forces, torsion, and bending of the cable in the vicinity of the packing.
3. Determination of means to prevent extrusion of the packing through the clearance space.
4. The establishment of optimum design proportions for cable glands, including design for economy and ease of assembly.
5. A study of gland sealing at pressures in excess of 500 psi.

1.2 Introduction

Research conducted at the Applied Physics Laboratory in 1954 led to the design of the interference cable seal which, for reasons which the following study will make clear, offers several advantages over the older compression type cable gland. One of the basic insights of the study was the recognition of the superior design of the widely-used O-ring as a sealing device against ambient hydrostatic pressure, and the application of the same interference principle to cable packing glands. Like the O-ring, the interference cable seal establishes an automatic seal which eliminates the need for a compression adjustment. Thus, the tightening of a gland nut, which is a critical and exacting procedure in the application of compression cable glands, is no longer required. The interference seal is automatic in the sense that once the cable is passed through the packing no further compression adjustment is required. The initial pressure established against the cable as it is passed through the packing remains in constant excess of whatever additional pressures are generated (within the test parameters of this study) by increased depth and hydrostatic pressure.

1.2.1 TYPICAL CABLE GLANDS

Early glands which were devised to prevent water leakage at the point of entry of insulated electrical cable into a bulkhead were typically of the type illustrated in Figure 1-1. Of these compression type cable glands, the simplest assemblies, (a) and (b), consist of a housing or gland body, a rubber packing, a packing nut, and a washer or bushing to prevent relative motion between the nut and the packing when the nut is rotated. Packing shapes shown in (a) and (b) are used extensively. Although no evidence has been found to this effect, it is assumed that the trapezoidal shape shown in (b) is intended to increase the pressure between the packing and cable through a wedging action when the nut is tightened. For convenience in assembly and disassembly an additional washer or bushing is frequently used between the packing and the bottom of the gland, as shown in (c). This allows for a larger hole through the gland body and alleviates a difficulty which is sometimes experienced in disassembly due to the tendency of the rubber packing to stick to the bottom of the gland after a prolonged period under pressure.

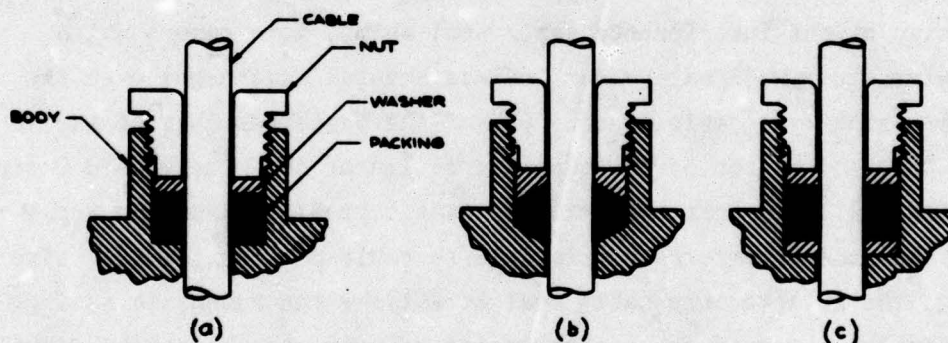


Figure 1-1. Typical Compression Type Cable Glands

1.3 An Analysis of Sealing Action

Before examining the interference cable seal, a general analysis of sealing action will clarify the principles of sealing and provide a theoretical basis for comparing the performance of the interference seal with that of the compression cable gland.

1.3.1 STRESS-STRAIN RELATIONSHIPS IN A TRI-AXIAL STRESS SYSTEM

As explained in Section 1.2, the compression type of cable packing gland now in wide use is dependent upon the axial compression of a rubber packing to the point where the rubber is upset radially and compressed against the cable and the surrounding gland wall. In analyzing the behavior of such a seal, it is well to consider the behavior of an elastic material under a tri-axial stress system.

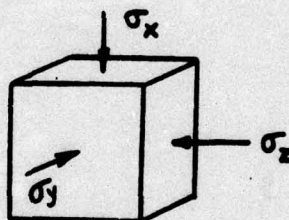


Figure 1-2. The Tri-axial Stress System of the Seal

In Figure 1-2, an elementary cube of an elastic material undergoes stress on its three pairs of opposite faces according to the unit compressive stresses σ_x , σ_y , and σ_z . (For convenience, compressive stresses and strains are considered positive in sign.) Assume that E represents the modulus of elasticity for the material and μ its Poisson ratio. Unit strains in the three directions are denoted by ϵ_x , ϵ_y , and ϵ_z , and are evaluated as follows:

$$\begin{aligned}
 (a) \quad \epsilon_x &= \frac{\sigma_x}{E} - \frac{\mu}{E} (\sigma_y + \sigma_z) \\
 (b) \quad \epsilon_y &= \frac{\sigma_y}{E} - \frac{\mu}{E} (\sigma_x + \sigma_z) \quad \dots \dots \dots (1) \\
 (c) \quad \epsilon_z &= \frac{\sigma_z}{E} - \frac{\mu}{E} (\sigma_x + \sigma_y)
 \end{aligned}$$

If four faces of the cube are prevented from expanding (as by rigid constraining walls) when a pressure is applied to the other pair of faces, then a pressure will be induced on the restrained faces. If the pressure applied to the two free faces is σ_x , then the induced pressure $\sigma_y = \sigma_z$ on the restrained faces may be determined from Equation 1(b) by substituting $\epsilon_y = 0$ and $\sigma_z = \sigma_y$. Then,

$$0 = \frac{\sigma_y}{E} - \frac{\mu}{E} (\sigma_x + \sigma_y)$$

from which

$$\sigma_y = \sigma_z = \sigma_x \left(\frac{\mu}{1-\mu} \right) \quad \dots \dots \dots (2)$$

From Equation 2 it is seen that the amount of the induced pressure is dependent only upon μ , the Poisson ratio for the material, and σ_x , the applied pressure.

If incremental pressures $d\sigma_x = d\sigma_y = d\sigma_z$ are applied to an initially unstressed cube L inches on a side, the volume of the cube will be reduced by an amount dV . Since the initial volume, V , equals L^3 , then

$$dV = 3L^2 dL = 3L^3 \frac{dL}{L} = 3V \frac{dL}{L}$$

and

$$\frac{dV}{V} = 3 \frac{dL}{L} \quad \dots \dots \dots (3)$$

From Equation 1(a), substituting $d\sigma_x = d\sigma_y = d\sigma_z$, and noting that, for a homogeneous material, $\epsilon_x = \epsilon_y = \epsilon_z = \frac{dL}{L}$,

$$\frac{dL}{L} = \frac{d\sigma_x}{E} - \frac{\mu}{E} (d\sigma_x + d\sigma_x)$$

or

$$\frac{dL}{L} = \frac{d\sigma_x}{E} (1-2\mu) \quad \dots \dots \dots (4)$$

Combining Equation 4 and Equation 3,

$$\frac{dV}{V} = \frac{3d\sigma_x}{E} (1-2\mu)$$

or

$$\frac{d\sigma_x}{\frac{dV}{V}} = \frac{E}{3(1-2\mu)} \quad \dots \dots \dots (5)$$

Equation 5 defines the bulk modulus of elasticity, $\frac{d\sigma_x}{\frac{dV}{V}}$, in terms of the elastic properties E and μ .

1.3.2 MECHANICAL PROPERTIES OF PACKING MATERIALS

The most common packing material for cable gland seals is rubber or rubber-like compounds. Rubber is often said to be incompressible (see pp. 362-368 of Reference 4). Actually, the compressibility of rubber is about the same as that of water (see p. 38 of Reference 3), which, at atmospheric pressure and 70°F, has a bulk modulus of elasticity of about 320,000 psi (see p. 6-04 of Reference 6). The modulus of elasticity in compression depends upon the rubber compound and ranges from 180 psi to 510 psi for soft rubbers (40-70 durometer) at room temperatures (see p. 22 of Reference 4).

By substituting the above values into Equation 5, it may be seen that for soft rubbers $\mu = 0.499$ or 0.500 for practical purposes. By placing this value into Equation 2, it is apparent that rubber, when confined, transmits pressure in much the same manner as a fluid.

Other packing materials such as leather, felt, graphited asbestos fiber, and rubber-cork compounds are considerably more compressible than rubber, so that the Poisson ratio (if such a property may be defined for these materials) is considerably less than 0.500. For cork, μ can be taken equal to zero (see p. 51 of Reference 12).

1.3.3 GLAND BEHAVIOR

It is seen, therefore, that in glands where rubber packing is used the sealing pressure, P_s , exerted by the packing against the cable and the gland wall is approximately equal to the axial pressure, P_a , applied by the gland nut. The pressure P_s is always slightly less than P_a , however, since 1) a small initial axial pressure is required before the packing fills the clearance space which is provided for ease of assembly; and 2) the cable surface undergoes an appreciable deformation and hence cannot be considered as a rigid restraint for the packing. The above effects are illustrated in Figure 1-3. In order to prevent leakage of fluid past the seal the gland nut must be tightened until P_s is somewhat in excess of the fluid pressure, P_f . As was pointed out in Section 1.2, the tightening operation is a critical procedure and may result in either a leaky gland or a damaged cable if not performed correctly.

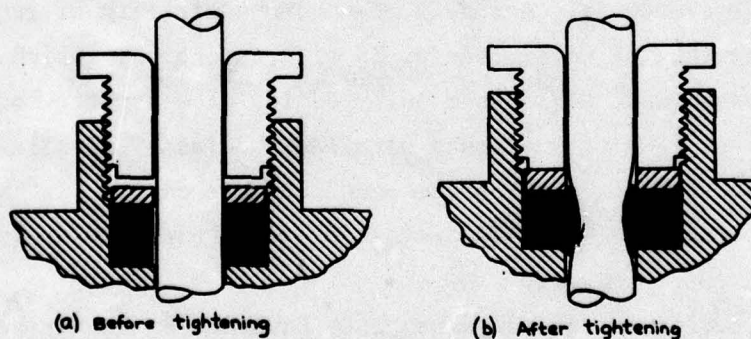


Figure 1-3. Effect of Tightening a Compression Cable Gland

Considering next the possible paths of fluid leakage through the gland, assume, as is usually the case, that all metal-to-metal contact surfaces are imperfectly fitted and will permit leakage between them. The seal then depends upon the ability of the soft packing to conform under pressure to the surface irregularities of the gland body and the cable covering.

In the compression glands shown in Figure 1-1, (a) and (b), two leakage paths are possible. Fluid must pass either 1) between the packing and the cable; or 2) past the outer circumference of the packing and then between the packing and the bottom of the gland. It is sufficient therefore that adequate pressure exist on the inner and bottom surfaces of the packing. This is a possible justification for the shape of packing shown in Figure 1-1(b), since pressure on the outer circumference of the packing is not necessarily critical. In the gland shown in Figure 1-1(c), however, leakage must be stopped by pressures at the inner and outer circumferential surfaces of the packing since fluid may now pass between the lower bushing and the bottom surface of the gland body. Hence a packing of rectangular cross section seems more desirable here, especially if the packing is short. The combination of radially inward cable deformation and the possible wedging action of a trapezoidal packing section (Figure 1-1(b)) might result in a lessening of pressure on the outer circumference, thereby causing a leak.

If we may assume that the nut has been correctly tightened it would appear that the seal is safe. There are two factors, however, which tend to decrease the sealing pressure, P_s , after assembly. The first factor is the creep or cold flow of the plastic or rubber cable covering, either axially away from the packing or into the voids between electrical conductors inside. The second factor is the tendency of the packing itself to flow into the increased clearance space opened by the compression of the cable. Both of these actions result in a decrease of volume of material within the gland space. Since the rubber packing is virtually incompressible it is apparent that only a small volume of material must be squeezed out in order to cause a considerable decrease in the pressure exerted by the packing upon its surroundings. Hence, it is possible that leakage may occur after the seal has been assembled for some period of time.

The application of fluid pressure to the compression type of gland has no appreciable effect upon the pressures within the system. Since P_f must be less than P_s and since, as explained earlier, P_s is less than P_a , the fluid pressure can act only upon the small areas exposed by the clearance spaces on the upstream side. If P_f is increased until it exceeds P_s , danger of leakage exists. It may therefore be concluded that the effectiveness of this type of seal depends almost entirely upon the skill of the mechanic who tightens the gland nut and upon the creep resistance of the cable and packing materials.

1.4 Interference (Automatic) Seals

Most of the shortcomings of compression cable seals in current use can be eliminated if a seal of the automatic or self-sealing type is utilized for underwater cable applications. The term "automatic seal" is here used to describe any arrangement of sealing elements in which the fluid pressure, P_f , activates the seal causing a pressure on the sealed surfaces, P_s , that is sufficient to prevent leakage. An automatic seal eliminates the necessity for correct tightening of a gland nut. Only a small initial seal pressure is required to start the automatic action of the seal. The second advantage is the diminished importance of such factors as cable creep, since the activating force, namely the fluid pressure, remains fully intact in spite of such action.

1.4.1 INTERFERENCE SEAL BEHAVIOR

For several years a packing known as the O-ring has found wide acceptance for many applications. It consists of a molded rubber ring, usually round in cross section, which is assembled between more or less rigid parts, one of which is grooved to accommodate the ring. Figure 1-4 illustrates a typical O-ring installation. The ring cross section is compressed by about 10 percent of its diameter (as per manufacturers'

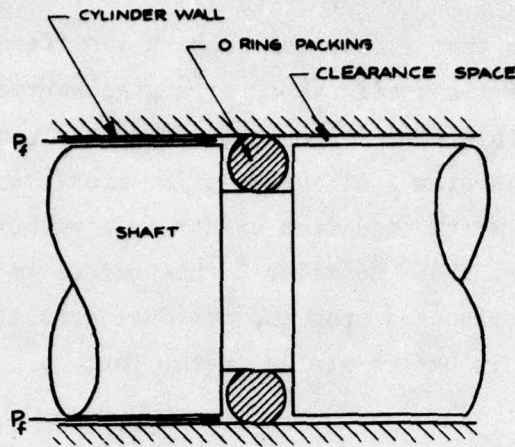


Figure 1-4. A Typical O-ring Installation

standard recommendations) upon assembly. When fluid pressure is applied to one side, the ring slides over against the opposite side of the groove and blocks the possible paths of leakage. The seal remains effective until the O-ring wears out due to relative motion of the parts or until extreme pressures cause an extrusion of the ring through the clearance space between parts. Packings of this type are sometimes made with a cross section that is square or of some other shape.

White and Denny conducted an experimental investigation covering many aspects of the use of this type of seal (see Reference 14). On measuring pressures upon the various surfaces of these packings, it was found that the pressure upon the circumferential surfaces is the sum of the fluid pressure and the initial pressure resulting from interference between parts. Thus $P_s > P_f$ at all times and the seal satisfies the basic requirement as stated in conclusion 1 of Section 1.1.1.

A logical explanation for this distribution of pressures results from a consideration of the elastic properties of rubber, as outlined in Section 1.3. It was here pointed out that for rubber μ is very nearly 0.500. Substituting this value into Equation 2, Section 1.3.1, it is seen that $\sigma_y = \sigma_z = \sigma_x$, or that the application of pressure to opposite sides of a piece of confined and initially unstressed rubber results in an equal pressure induced upon the confined surfaces. In this way, rubber transmits pressures in the same manner as a fluid. Rubber differs

from a fluid, however, in that rubber can support a difference of principal stresses by virtue of its static shear strength, whereas a fluid cannot. It is thus possible that a piece of rubber may contain a residual stress system in which the principal stresses (or pressures) are not equal in all directions, which condition exists in a rubber packing compressed as shown in Figure 1-4. Equation 2 then refers to those pressures or stresses that are superimposed upon the residual stress system. In view of this, Equation 2 is better stated in the form

$$\Delta\sigma_y = \Delta\sigma_z = \Delta\sigma_x \left(\frac{\mu}{1-\mu} \right) \dots \dots \dots (6)$$

For rubber, then, $\Delta\sigma_y = \Delta\sigma_z = \Delta\sigma_x$, very nearly.

The application of this relationship is best seen by considering the action of an interference packing of rectangular cross section, as shown in Figure 1-5. The initial pressure P_0 exists by virtue of the initial compression of the rubber between the metal parts. The application of fluid pressure to the system results in the pressure relationships shown in Figure 1-5(b) and the fluid is prevented from leaking past the circumferential contact surfaces. (For simplicity, pressures are shown to be uniformly distributed over the surfaces. This is not strictly true, but the principle still applies (see Reference 13).) Although it is not necessarily apparent from the preceding explanation, packing of circular and other cross sections behaves in the same manner, as indicated by measurements made by White and Denny (see Reference 13).

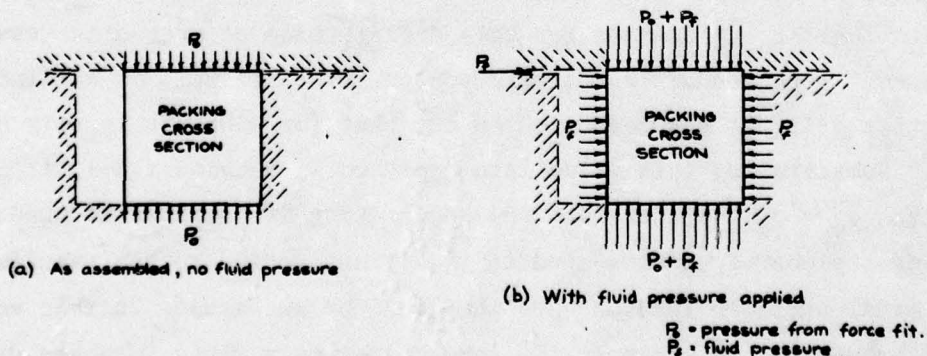


Figure 1-5. Action of a Rubber Interference Seal Under Fluid Pressure

In applying the interference principle to a cable gland seal, it is apparent that the packing must be of considerably different proportions than those for standard O-rings in order to allow for the decrease in cable diameter due to pressure (see p. 18-03 of Reference 7). With sufficient interference, however, it has been found in experiments which are later described that the interference principle is fully applicable to cable seals.

This type of seal possesses several unique advantages. Its action is fully automatic but does not depend upon the cable extrusion force. Hence its action is not affected by tensile loads on the cable nor by clamping the cable inside the gland to prevent its extrusion into the vessel. The seal is not dependent upon friction nor is it adversely affected by friction between surfaces. Another feature of this seal which should be advantageous at higher pressures is that the pressure on the sealed surfaces is only a relatively small amount in excess of the fluid pressure--just enough to prevent leakage. Thus the possibility of damaging the cable by overcompression is minimized. For these reasons and because of the fact that O-rings and similar packings employing this principle have proved to be highly dependable as static seals, it is felt that the interference type of cable seal will become a highly dependable application.

1.5 Experimental Investigation of Interference Seals

In the section that follows, several tests are outlined which use equipment specifically designed or modified to simulate hydrostatic pressures of up to 500 psi.

1.5.1 PRELIMINARY TESTING

At the beginning of the investigation of cable sealing problems, a brief test was conducted to determine the effectiveness of the seals

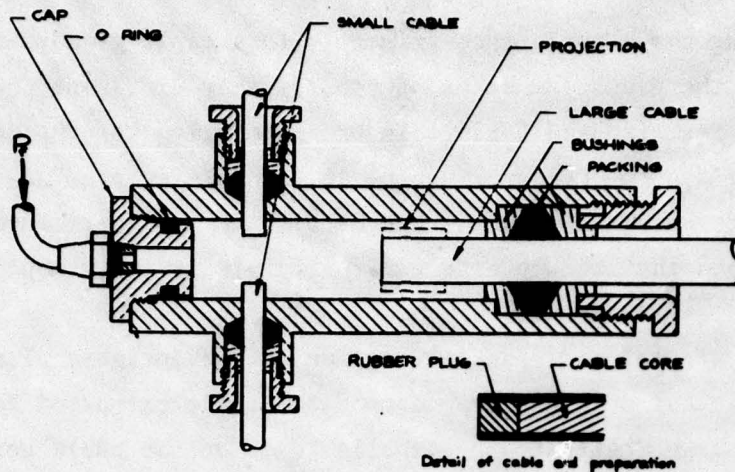


Figure 1-6. Molded Cable Junction Chamber

on an underwater cable junction chamber in current use. In this chamber, made of brass, five seals were incorporated. The chamber, as modified for test purposes, is illustrated in Figure 1-6. A large (approximately 0.60 inch diameter) cable entered at one end and was sealed by a gland of the type shown in Figure 1-1(c), Section 1.2.1, except that the packing used was of trapezoidal cross section. At the opposite end, a metal cap was sealed with a standard O-ring. Three smaller cables (approximately 0.30 inch diameter) entered the chamber radially near one end and were sealed with glands of the type shown in Figure 1-1(b), Section 1.2.1. All packings were molded of neoprene, approximately 40 durometer. The larger cable was covered with a vinyl plastic of about the same mechanical properties as ordinary plastic garden hose. The smaller cables were covered with neoprene of about the same hardness as the packings.

Since no high-pressure container was available of sufficient size to accommodate the entire sealed junction chamber, it was decided to fill the chamber with water and to apply inside pressure. This also permitted the immediate observation of any leakage. A pressure fitting was installed in the end cap and the inner ends of the cables were sealed by cementing rubber plugs inside the cable covering as shown in the detail in Figure 1-6.

Test results showed that, once applied hydrostatic pressure reached the initial radial pressure created by tightening the gland nut, the seal

leaked. Alternate tightening of the nut and application of fluid pressure established clearly that the sealing effectiveness of the compression glands increased with the initial load on the packing. A very heavy torque on the packing nut was necessary to seal pressures in excess of 300 psi.

Once the initial leakage point had been reached, rapid application of additional pressure to the system would commonly raise the pressure to the point where leakage stopped. In each case, similar patterns of leakage occurred, with an intermediate pressure range in which there was leakage. (For a more complete explanation of the mid-range leakage phenomenon in compression cable glands, see Chapters 4 and 5 of Reference 8.)

1.5.2 TESTS USING A BRASS PRESSURE UNIT

Further investigation of the theory and action of the interference type of automatic seal was initiated, using a specially designed pressure unit.

1.5.2.1 Apparatus. The test unit was built as illustrated in Figure 1-7. The cable was passed directly through the pressure chamber and sealed at either end of the chamber by a packing gland. Thus the cable extrusion force was eliminated and the seal depended on the action of the packing alone.

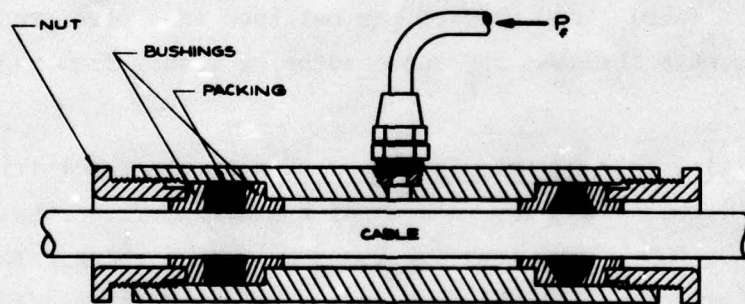


Figure 1-7. Brass Pressure Test Unit

Four sets of bushings were made for this unit, two to accommodate trapezoidal packings and two to accommodate rectangular packings. The inside diameter of the bushings was just large enough to accommodate the

cable when assembled by hand. The bushing O.D. was made 0.010 inch smaller than the gland body diameter. The glands on this unit were of the same general dimensions as the large gland on the junction chamber used in the preliminary test. The cable used was vinyl-covered, multi-conductor, twisted cable with an overall diameter of about 0.60 inch. The inside diameter of the gland body (nominal O.D. of the packing) was 1.38 inch.

1.5.2.2 Manufacture of Test Packings. Molded trapezoidal packings, identical to those used in the preliminary test, were available from stock supplies. These packings, as before, formed a clearance fit with the cable and gland wall. To save time and expense the rectangular-section packings were cut from rubber sheet. This way, the dimensions could be adjusted as desired without depending upon a mold of fixed size. In this and later tests, rectangular-section packings were cut from 40-50 durometer neoprene sheets, 1/8 inch and 1/4 inch thick. Holes were made in the sheet with arch punches (sharpened tubular shape) by wetting the punch with soapy water and rotating the tool by hand as it was pushed through the sheet. This method produced a fairly clean cut and was found to be satisfactory. An approximate outside diameter was cut with scissors, leaving a margin for finishing. A stack of packings was then placed upon a mandrel and the desired outside diameter was obtained by sanding with emery cloth at high speed in a lathe. A fairly good surface was obtained if a fine grade of emery was used to remove the last few thousandths of rubber from the outside diameter.

1.5.2.3 Initial Test of Interference Packings. In the initial test with this unit, each gland was made up of a stack of five rubber packings, 1.41 inches O.D., 0.50 inch I.D., and 0.13 inch thick. The interference was therefore about 1/8 inch at the hole and about 1/32 inch at the outside diameter. The packing was slightly longer than one cable diameter. The packings, cable, and gland body were lightly lubricated with a silicone grease to facilitate assembly. Slight difficulty was encountered during assembly when air became trapped between the individual packing laminations. This was overcome by the temporary insertion of a small wire between the packing and the gland body, compressing the packing

locally and providing tiny openings for the escape of the air. The packing nuts were tightened by hand to make the packings lie flat, then backed off to relieve any initial axial pressure on the packing.

Fluid pressure was applied and measured with the same equipment used in preliminary testing, except that a globe-type shutoff valve was incorporated in the hose line.

Pressure was gradually applied until the gauge limit of 800 psi was reached. No trace of leakage was observed. The pressure was then slowly decreased, again without leakage. This process was repeated several times, and the seals proved to be completely successful.

A pressure of 800 psi was then applied to the unit and the shutoff valve closed. The unit was left overnight under pressure, without a trace of gland leakage. (The pressure dropped to 300 psi, due to slight leakage at the shutoff valve and some creep of the cable covering through the glands.) At 300 psi, the cable was pushed back and forth through the unit and rotated but the seals held.

The pressure was then decreased and the unit disassembled for inspection. In each gland, some permanent set was observed in the two downstream laminations, indicating some extrusion of the packing between the cable and the downstream bushing. The remaining laminations were apparently unaffected.

The unit was then reassembled, using only three laminations in each packing. Another overnight pressure test was made, the results being the same as before.

The unit was assembled again with five laminations in each gland, and a pressure of about 500 psi was maintained for a period of forty-eight hours. No leaks occurred and the appearance of the laminations was as previously observed.

1.5.2.4 Interference Packing vs Compression Packing. In order to compare the actions of the interference seal with one of the compression type, a trapezoidal-section packing gland was installed in one end of the unit, the other gland being the same as before. The compression gland nut was then tightened and pressure applied to the system. The compression gland leaked at about 80 psi. The packing nut was tightened further, as in the preliminary testing, and the pressure raised. Another

leak occurred at about 150 psi. Rapid pumping of the hydraulic cylinder raised the pressure in the system, but the leakage continued. No "upper limit" could be found at which leakage would stop. As before, the effectiveness of this gland was directly proportional to the initial pressure applied by the packing nut. When this initial pressure was overcome by fluid pressure, leakage resulted. It was also found that the fluid pressure capacity of this gland decreased with time if the nut was not continually tightened, the amount of decrease being about ten percent in twenty minutes, thirty percent in two hours.

The interference gland did not leak at any time, even though the packing nut was loose.

This test was repeated, substituting a laminated rectangular "clearance" packing for the trapezoidal shape. The behavior of this gland was similar to the gland containing the trapezoidal packing, indicating that the initial fit of the packing with its surroundings is a critical factor.

1.5.3 TESTS USING A TRANSPARENT PRESSURE CHAMBER

For further investigation of interference glands, another test unit was built incorporating a transparent plastic (Lucite) pressure chamber.

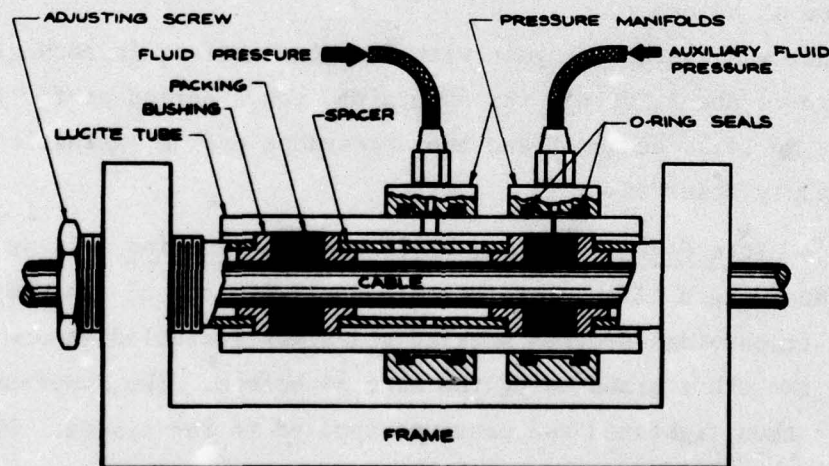


Figure 1-8. Packing Test Unit with Transparent Pressure Chamber

1.5.3.1 Apparatus. The assembled unit is illustrated in Figure 1-8. Because of the relatively low strength of the plastic, a different type of construction was employed than had been used with the previous test units. In this case a frame was built from steel channel sections to support the axial thrust of the fluid pressure upon the gland assemblies. A tubular adjusting screw was provided at one end of the frame for positioning the packings and, if desired, exerting an axial compression upon the packings. Axial loads from the adjusting screw were transmitted to both packings by means of a clear plastic tubular spacer placed between the two inner bushings. A number of holes were drilled in the spacer to permit fluid to fill completely the space between packings. To avoid the problem of attaching a pressure fitting to the somewhat brittle Lucite tubing, it was decided to encircle the tube with an annular metal pressure manifold, sealed at either end by O-rings. A pressure fitting was threaded into the cylindrical wall of the manifold. The fluid under pressure was transmitted to the inside of the Lucite tube through a hole drilled in the tube wall, the manifold being positioned so as to include this hole between the O-ring seals.

To permit the measurement of pressure on the packing surface, a small (0.014 inch dia.) hole was drilled through the wall of the tube near one end. A second pressure manifold, identical to that described above, was used to apply a fluid pressure at the small hole.

Further construction details for this unit are shown in the photographs in Figures 1-9, 1-10 and 1-11.

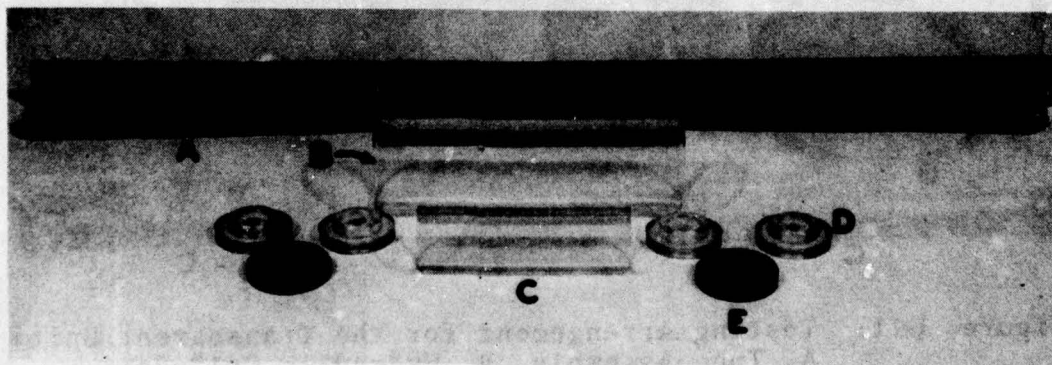


Figure 1-9. Parts of the Transparent Tube Assembly:
A. Cable, B. Lucite Tube, C. Spacer,
D. Bushing, E. Packing

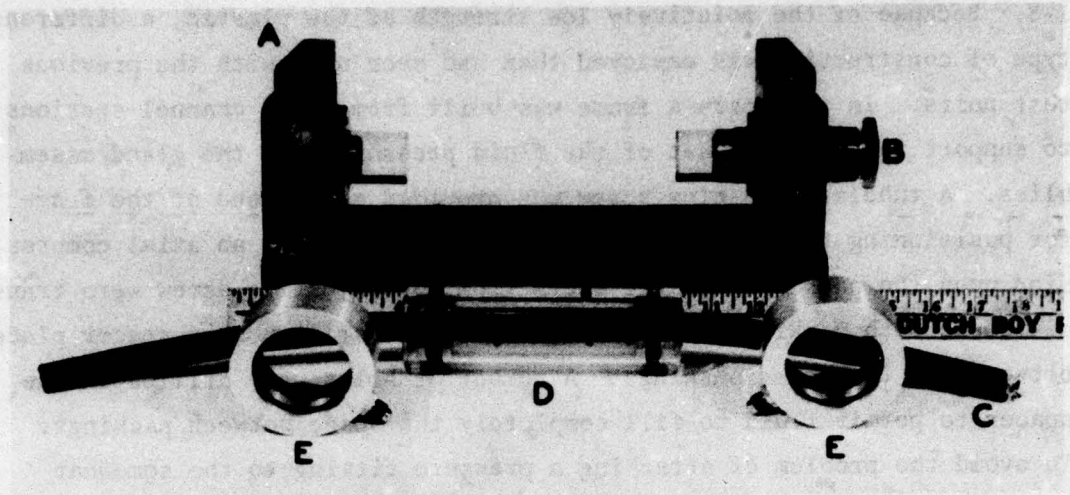


Figure 1-10. Parts of the Test Unit: A. Frame, B. Adjusting Screw, C. Cable, D. Tube Assembly, E. Pressure Manifolds

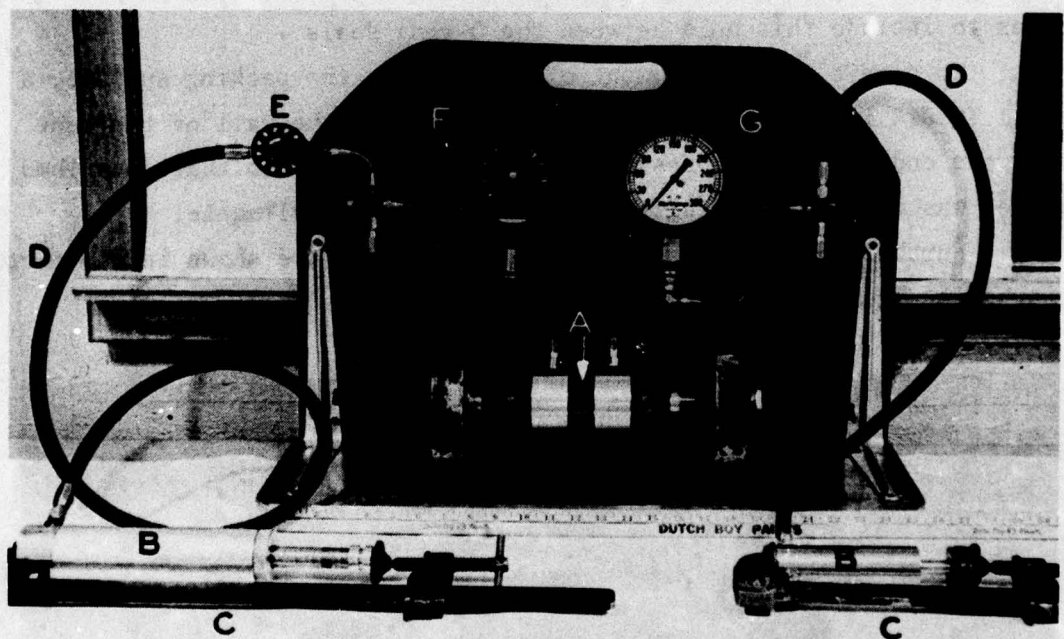


Figure 1-11. Testing Arrangement for the Transparent Unit: A. Tube Assembly, B. Hydraulic Cylinders, C. Screw Clamps, D. Flexible Hose, E. Shutoff Valve, F. Main Pressure Gauge, G. Auxiliary Pressure Gauge

1.5.3.2 Technique of Measuring Seal Pressure. The technique employed in measuring pressure upon the outer circumferential surface of the packing was suggested by White and Denny (see p. 35 of Reference 13). An auxiliary fluid pressure is applied through the small hole to the surface of the packing in contact with the tube wall. When the fluid pressure equals the sealing pressure, the packing is lifted from contact and the auxiliary fluid escapes, either to the system or to the atmosphere. The small hole could be moved to cover different portions of the packing face by sliding the Lucite tube in an axial direction with respect to the packing.

Two pressure gauges were employed, one for measuring the fluid pressure applied to the inside of the tube, the other for measuring the auxiliary fluid pressure applied at the small hole over the packing. These gauges were calibrated and adjusted to give identical readings under the same fluid pressure.

Pressures were applied to the manifolds from water-filled hydraulic cylinders connected to the manifolds by flexible hydraulic hose. Screw-type clamps were employed to compress the hydraulic cylinders.

1.5.3.3 Test of Unit. The unit was assembled using laminated neoprene interference packings, similar to those used in the brass test chamber, and fluid pressure was gradually applied up to 800 psi to determine whether the strength of the unit was adequate. The adjusting screw (Figure 1-8) was not tightened. The packings sealed successfully, as before, and the unit worked as planned.

An attempt was made to measure the sealing pressure on the circumference of the packings by the method described above. When adequate auxiliary fluid pressure was applied, the fluid entered the packing between laminations, which sealed on either side, forming a small separate pressure chamber which held pressure up to the limit of the gauge. At the time of this test a 0-300 psi gauge was used to measure the auxiliary pressure. No larger gauge was immediately available other than a 0-800 psi gauge which was used to measure the main fluid pressure. Even when the small hole was positioned near the downstream end of the downstream lamination, the auxiliary fluid entered between this and the next lamination.

To avoid this difficulty, one-piece packings were cut from 40 durometer neoprene sheet, 1/4 inch thick. The holes were cut with a 1/2-inch arch punch, and the outside diameters were finished with emery cloth, as before, to measure 1.53 inches. The inside diameter of the Lucite tube was 1.50 inches and the cable diameter was 0.60 inch, as before.

1.5.3.4 Fluid Pressure vs Seal Pressure. The unit was assembled without axial pressure from the adjusting screw, and a fluid pressure of 800 psi was applied inside the tube. Even at this pressure, the 1/4-inch packings sealed successfully. The internal pressure was subsequently reduced to 200 psi. The small hole was then positioned at about the center of the packing face, and when sufficient auxiliary pressure was applied the auxiliary fluid escaped into the main pressure chamber.

The main fluid pressure was then relieved altogether and the interference pressure on the packing face was measured by positioning the small hole at a series of axial locations along the packing. The interference pressure was found to be 12 psi, uniform along the packing from end to end.

At the completion of this measurement, a main fluid pressure of 295 psi was applied inside the tube, creating a sealing pressure of 300 psi at the center of the packing face. The main fluid pressure was then gradually reduced. At the same time the auxiliary pressure decreased of its own accord as fluid escaped into the system. Simultaneous readings were taken on the two pressure gauges so that the difference in pressures could be determined. The results, tabulated in Table 1-1, verify the theory of interference seal mechanics. The seal pressure P_s remained a relatively constant amount greater than the fluid pressure P_f . Actually the difference of pressures was less at higher pressures, probably because of deformation of the cable inside the packing. (A subsequent test, in which the cable was replaced by a 5/8-inch diameter metal rod, showed a constant difference between P_s and P_f of 23 psi throughout the full range of pressures.)

1.5.3.5 Distribution of Pressure on Packing Face. During the above test, whenever pressure existed in the main system, the auxiliary

Table 1-1. Values of Fluid Pressure (P_f) and Seal Face Pressure (P_s) on an Interference Cable Gland with No Axial Tightening (pressures measured in psi)

P_f	0	19	29	39	60	90	110	131	151	172	192	215	234	255	273	295
P_s	12	30	40	50	70	100	120	140	160	180	200	220	240	260	280	300
$P_s - P_f$	12	11	11	11	10	10	10	9	9	8	8	5	6	5	7	5

fluid escaped into that system rather than to the atmosphere. This result was consistent, even when the small hole was located near the downstream end of the packing. In order to determine the cause of this phenomenon, the pressure distribution on the packing face was measured while a fluid pressure of 100 psi was maintained in the main system. A packing with somewhat greater interference was used in this test. A plot of the pressure distribution is shown in Figure 1-12 indicating an increasing pressure toward the downstream end. The measuring process was repeated with the ends of the packing reversed, the results being about the same as before.

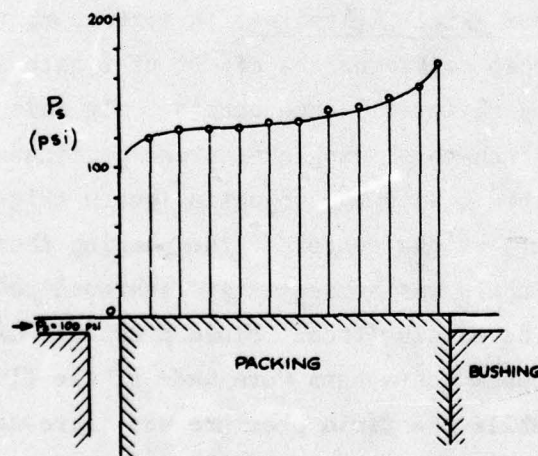


Figure 1-12. Pressure Distribution on Seal Face

A possible explanation for this distribution of pressure may be based upon the tendency of the cable covering to be extruded slightly through the gland when fluid pressure is applied within the chamber. The resulting friction between the cable covering and the packing may well cause the pressure on the downstream end of the packing to exceed that on the upstream end.

Pressure distribution along the packing was again measured at a fluid pressure of 100 psi, this time with a metal rod replacing the cable. A constant seal pressure of 128 psi was measured across the entire face of the packing except for a very narrow band at the downstream edge, where the pressure was measured to be 165 psi. As before, all auxiliary fluid escaped "upstream" into the main system. A possible cause of this peak pressure might be the wedging action of the corner of the packing as it was forced against the slightly chamfered face of the downstream bushing. Similar measurements were obtained, however, after the bushing was re-machined with a square corner. In exploring the pressure distribution on the outer surface of somewhat similar seals, White and Denny found no such pressure peak (see pp. 19 and 28 of Reference 13). No indication was given in this work, however, as to the direction of escape of the auxiliary fluid. At the present time, no satisfactory explanation has been found for the existence of a peak pressure at the downstream edge of the packing.

1.5.3.6 Effect of Axial Tightening. A further test was conducted with this equipment to determine the effect of tightening the gland nut in a gland employing an interference packing. In this test, the unit was assembled with 1/4-inch-thick single neoprene packings similar to those previously described. With the adjusting screw (Figure 1-8) loose, the interference pressure at the center of the packing face measured 12 psi. The adjusting screw was subsequently tightened to produce a pressure of 70 psi on the packing face. Fluid pressure was applied to the unit and simultaneous measurements were made of the fluid pressure and the seal pressure while the fluid pressure was increased. The results are tabulated in Table 1-2. Figure 1-13 shows the variation of sealing pressure margin ($P_s - P_f$) with the fluid pressure P_f . From this curve,

Table 1-2. Values of Fluid Pressure (P_f) and Seal Face Pressure (P_s) on an Interference Cable Gland with Initial Axial Tightening (pressure in psi)

P_f	0	38	68	100	125	148	170	191	212	233	256	273
P_s	70	80	100	120	140	160	180	200	220	240	260	280
$P_s - P_f$	70	42	32	20	15	12	10	9	8	7	4	7

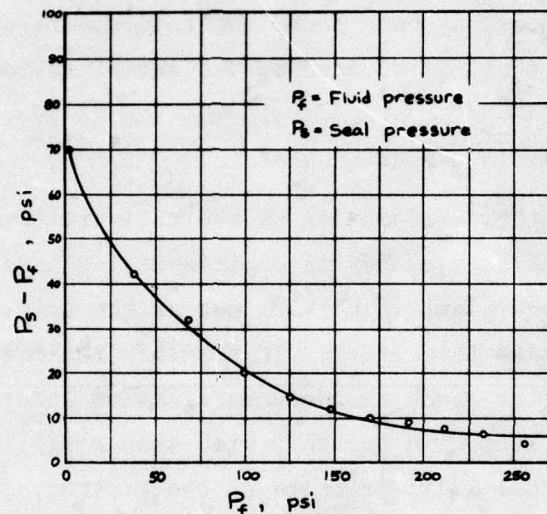


Figure 1-13. Effect of Axial Tightening on an Interference Packing.

it is evident that the initial margin of seal pressure provided by tightening the adjusting screw was soon overcome by the fluid pressure, after which time the seal continued to function as an interference seal. Similar results were obtained when the test was repeated, using higher initial tightening pressures. Hence, the effect of packing nut pressure is to increase the sealing pressure margin ($P_s - P_f$) until such fluid pressure is applied as to replace the pressure from the nut. The seal is then automatic, providing an approximately constant sealing pressure margin as the fluid pressure increases.

1.5.3.7 Leakage Caused by Twisting Cable. In all experiments thus far described, the cable core consisted of three main conductors, twisted together. This core was encased in a vinyl cover. The result was a moderately firm cable which was not truly round. When under pressure, the covering was forced between the conductors, forming spiral creases in the surface. This cable was picked for experimental purposes, since it was considered more difficult to seal than firmer coaxial types.

During several of the tests, it was observed that leakage would occur between the cable and the packing when the cable was severely twisted at its free ends. This occurred only at pressures over about 275 psi. In other instances, no leak would occur when the cable was twisted.

As yet, no remedy has been found for this condition, although little time has been thus far devoted to its investigation.

1.5.4 AN EXPERIMENTAL INTERFERENCE SEAL

To provide further information on the reliability of interference packings for cable seals, a number of experimental glands were incorporated in underwater equipment in current use at the University of Washington's Applied Physics Laboratory. To simplify the construction of the glands and to better check the dependability of interference packings, the gland assemblies were held together with snap rings in such a way as to produce no initial axial pressure on the packing. Figure 1-14 illustrates the construction of these glands. The cables in each case were of the coaxial type, being 0.40 inch in diameter and of fairly firm construction. The cable covering was a vinyl plastic. The packings were 1/4-inch-thick neoprene, 40 durometer, and two packings were used in each gland. The gland body diameter was 1.375 inches. The interference between the cable and packing was about 0.15 inch and that between the packing and the gland body was 0.03 inch.

Two units employing these glands were assembled at opposite ends of a short length of cable. The units and cable were then placed in a high-pressure vessel and subjected to an external water pressure of 500 psi. No evidence of leakage was present when the glands were disassembled.

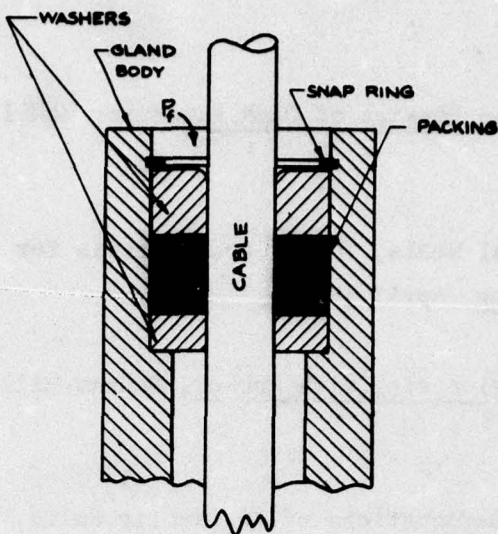


Figure 1-14. An Experimental Interference Seal

1.6 Cable Seal Design

The interference cable seal has gained wide use since this study was originally made. For details on design for an interference cable family used by the Applied Physics Laboratory, see Section 2 of this manual--"A Standard for Simple Interference Cable Seals."

1.7 References

1. Bridgman, Percy F., The Physics of High Pressure, McMillan, N.Y., 1931.
2. Brkich, A., "Mechanical Seals, Theory and Criteria for their Design," Product Engineering, April 1950.
3. Burton, Walter E., Engineering with Rubber, McGraw-Hill Book Co., Inc., N.Y., 1949.
4. Chilton, E.G. "Large Deformations of an Elastic Solid," Journal of Applied Mechanics, Dec. 1948.
5. Dayton, E.R., "Hermetic Sealing," Sperry Engineering Review, Volume 6, No. 5, September-October 1953.
6. Eshbach, Ovid W., Handbook of Engineering Fundamentals, 2nd Ed., John Wiley and Sons, N.Y., 1952.
7. Kent, William and Robert T. Kent, Design, Vol. II of Mechanical Engineer's Handbook, 12th Ed., John Wiley and Sons, N.Y., 1950.
8. Morrison, J.B., An Investigation of Cable Seals, Applied Physics Laboratory, University of Washington, Report No. 54-41, March 1, 1954. (Essentially a longer version of this manual section.)
9. Schmitz, C.E., "The Mechanical Seal," ASME Transactions, August 1949.
10. Sears, Francis W., Principles of Physics, Vol. I, Addison-Wesley Press, Inc., Cambridge, Mass., 1947.
11. Summary Technical Report, Div. 6, National Defense Research Committee, Washington, D.C., 1946, Vol. 12.
12. Summary Technical Report, Div. 6, National Defense Research Committee, Washington, D.C., 1946, Vol. 13.

13. Timoshenko, S., Strength of Materials, Part I, 2nd Ed.,
D. Van Nostrand Co., Inc., N.Y., 1940.
14. White, C.M. and Denny, D.F., The Sealing Mechanism of Flexible
Packings, Ministry of Supply, Scientific and Technical Memorandum
No. 3/47. H.M. Stationery Office, London, 1948.

Section 2

TABLE OF CONTENTS

<u>Section</u>	<u>Title</u>	<u>Page</u>
2.1	Introduction	2-1
2.1.1	Scope	2-1
2.1.2	Principle of Operation	2-2
2.2	General Description	2-2
2.3	Assembly Procedure	2-4
2.4	Design Specifications--Materials and Dimensions	2-5
2.4.1	Housing and Retaining Ring	2-6
2.4.2	Packing	2-8
2.4.3	Retaining Washer (Seal W/O Boot)	2-10
2.4.4	Retaining Washer (Seal with Boot)	2-12
2.4.5	Boot (Optional)	2-14
2.5	References	2-16

Section 2

LIST OF FIGURES

<u>Figure</u>	<u>Title</u>	<u>Page</u>
2-1	Interference Seal Assembly	2-3
2-2	Cut Cable End	2-4
2-3	Housing, with Retaining Ring Groove	2-6
2-4	Packing	2-8
2-5	Retaining Washer (Seal W/O Boot)	2-10
2-6	Retaining Washer (Seal with Boot)	2-12
2-7	Boot	2-14

LIST OF TABLES

<u>Table</u>	<u>Title</u>	<u>Page</u>
2-1	Housing and Retaining Ring Dimensions	2-7
2-2	Packing Dimensions	2-9
2-3	Retaining Washer Dimensions (Seal W/O Boot)	2-11
2-4	Retaining Washer Dimensions (Seal with Boot)	2-13
2-5	Boot Dimensions	2-15

Section 2

A STANDARD FOR SIMPLE INTERFERENCE CABLE SEALS

2.1 Introduction

The purpose of this standard is to establish recommended sizes, proportions and materials for the component parts of interference cable seals with single packings. The purpose of interference seals is to prevent leakage at the point of entry of electrical and similar cables into undersea vessels and bulkheads. They must effectively maintain seal integrity under substantial hydrostatic pressures and against corrosive action over lengthy periods of time.

All dimensions and materials given in this section are the design recommendations of James Morrison and are based directly on his test findings, as outlined in Section 1 of this manual.

2.1.1 SCOPE

This standard describes eight seal groups for sealing cables ranging from 0.100 inch to 1.120 inches in diameter. These simple interference seals are designed to seal smooth-jacketed cables of approximately circular cross section at pressures of up to 500 psi or 1150 feet in ocean depth. The 500 psi maximum design pressure is an arbitrary figure, dictated by the limitation of Morrison's test facilities when he undertook his design study of interference seals in 1954 (see Sections 1.5.3.3 and 1.5.4). In a 1957 article, Morrison indicated that he had subsequently tested the design to a pressure of 5000 psi without failure (see Reference 1). However, funds to systematically test the seal under varying conditions at such pressures have not been made available, and hence 500 psi remains the last pressure at which the design was thoroughly tested. Pressure limits for the inter-

ference seal seem to be determined by the crush strength of the cable, the stiffness of the retaining washer, the housing-to-washer clearance, and the creep strength of the seal (see Figure 2-1). This design provides only for the sealing mechanism and will not necessarily prevent cable extrusion (slippage of the cable through the packing) or cable rotation. It will be the responsibility of the designing engineer to provide suitable anti-extrusion and anti-rotation devices.

2.1.2 PRINCIPLE OF OPERATION

The action of the interference seal is automatic which means simply that once the cable is passed through the packing no additional compression adjustments are required. The initial pressure established by passing the cable through a packing of interference fit remains in constant excess of whatever additional hydrostatic pressure is generated through increased ocean depth. This sealing action is due to the properties of pliable solid rubber compounds which are readily deformed, but are practically incompressible. The seal requires no tightening or special preparation for immersion other than that provided by the fit of the packing with its surroundings and the fit of the cable with the packing. (For a theoretical discussion of Interference Cable Seals, see Section 1 of this manual.)

2.2 General Description

The simple interference seal assembly, shown in Figure 2-1, consists of 4-5 components, excluding the cable. These include:

- A) The Housing. The Housing Cavity is machined to standard dimensions, depending upon cable size, into the wall of the vessel or an extension thereof.
- B) The Packing. The Packing is a thick washer of soft, solid rubber, proportioned so as to have radial interference between the Housing wall and the cable when in place.

- C) The Retaining Washer. The metal Retaining Washer, along with the Retaining Ring, performs the function of holding the Packing--and, when used, the Boot--in place within the Housing.
- D) The Retaining Ring.
- E) The Boot (Optional). The Boot is optional and for simplicity may be omitted. It is a flanged sleeve of a somewhat harder grade of rubber than the Packing. Its purpose is to help support the cable against local bending and to provide a finished appearance to the seal assembly.

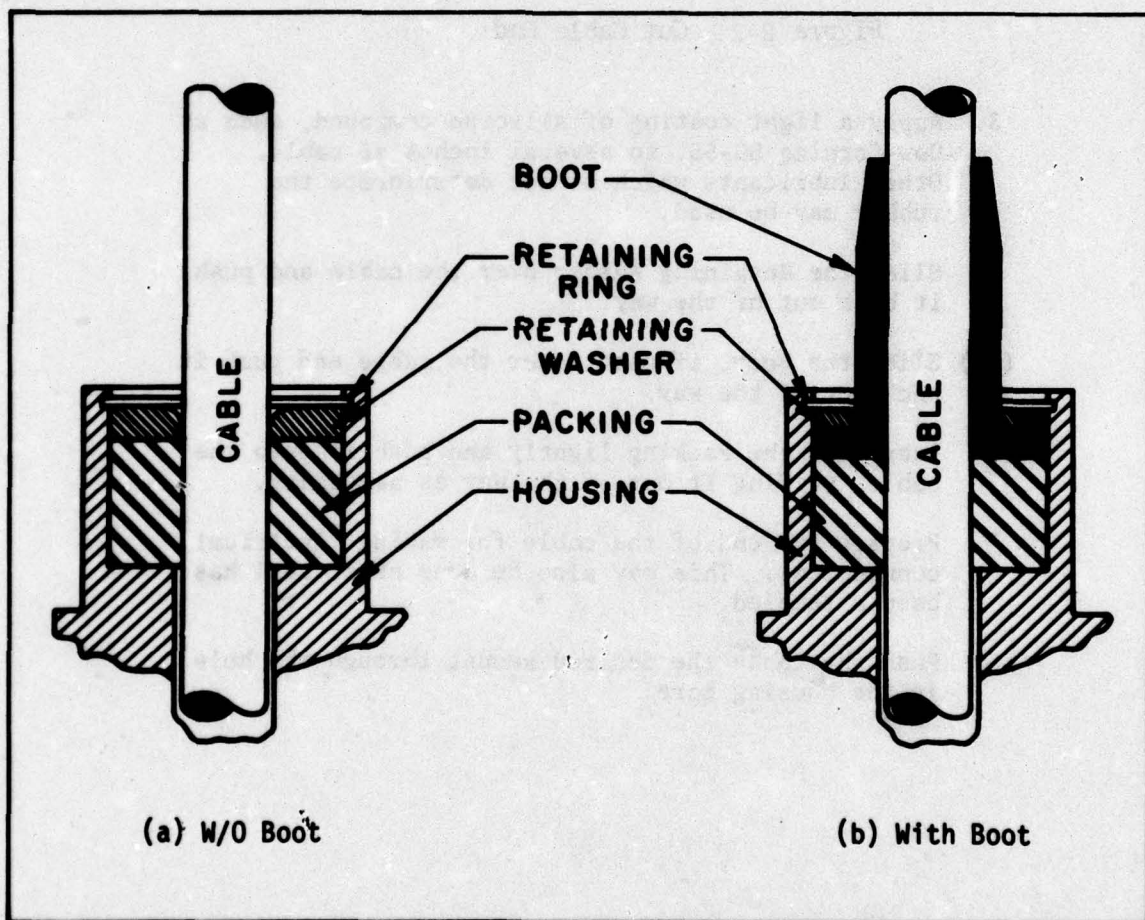


Figure 2-1. Interference Seal Assembly

2.3 Assembly Procedure

A) Recommended Method.

1. Determine whether the Boot will be used or not and assemble the appropriate parts.
2. Cut the end of the cable as shown in Figure 2-2, removing any sharp wire ends which protrude from the jacket.



Figure 2-2. Cut Cable End

3. Apply a light coating of silicone compound, such as Dow-Corning DC-55, to several inches of cable. Other lubricants which do not deteriorate the rubber may be used.
4. Slide the Retaining Washer over the cable and push it back out of the way.
- (5.) Slide the Boot, if used, over the cable and push it back out of the way.
6. Lubricate the Packing lightly and push it onto the cable, sliding it out of the way as necessary.
7. Prepare the end of the cable for making electrical connections. This may also be done after seal has been assembled.
8. Push the cable the desired amount through the hole in the Housing bore.

9. Push the Packing into the annular space between the housing and the cable. If the packing has been lubricated, this step is easily accomplished with thumb pressure only, provided that the Packing is not harder than 35 durometer. If additional pressure is required, use a blunt rod to force the cable through the Packing.
 10. Slide the Boot and/or Washer into place and fasten them with the Retaining Ring.
 11. Apply anti-extrusion and anti-rotation devices, as required (see section 2.1.1).
- B) Alternate Method. As an alternate method of assembly, the lubricated cable end, cut as shown in Figure 2-2, may be pushed through a preassembled gland.

2.4 Design Specifications—Materials and Dimensions

Eight standard sizes of seals are specified for sealing cables of sizes ranging from 0.100 inch to 1.120 inches in diameter. Each of the eight standard seal sizes covers a small range of possible cable diameters. *Seal proportions for cable sizes beyond this range may be determined by increasing or decreasing all dimensions in proportion to the cable diameter.*

2.4.1 HOUSING AND RETAINING RING

- A) **Housing Materials.** The Housing may be constructed from any non-porous metal or other material suitable for withstanding the anticipated pressure and the exposure to the corrosive action of sea water.
- B) **Retaining Ring Materials.** Should be of corrosion-resisting Steel.
- C) **Housing and Retaining Ring Dimensions.** See Figure 2-3 and Table 2-1, below. The length of the Housing bore (C) varies for a given cable, depending on whether or not the optional Boot is used.

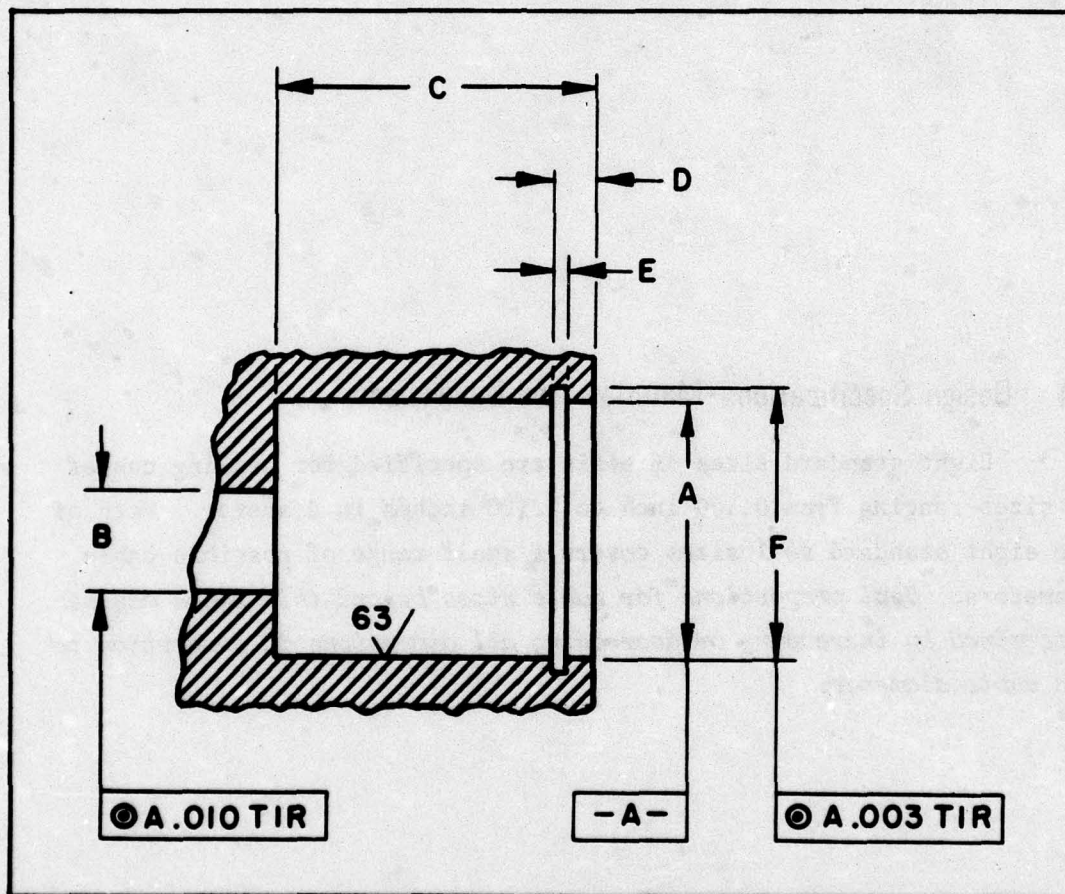


Figure 2-3. Housing with Retaining Ring Groove

Table 2-1. Housing and Retaining Ring Dimensions (in.)

Seal No.	Range of Cable Diameters	A ± 0.005	B 0.005 to 0.015 diametral clearance for particular cable used	C W/O Boot ± 0.005	C W. Boot ± 0.005	D ± 0.005	Retaining Ring		
							E	F	Truarc* Cat. No.
1	0.100 - 0.184	0.500	0.005 to 0.015 diametral clearance for particular cable used	0.485	0.500	0.100	0.039 +0.003 -0.000	0.524 ±0.003	N5000- 50- W
2	0.185 - 0.269	0.625		0.485	0.500	0.100	0.039 +0.003 -0.000	0.659 ±0.003	62- W
3	0.270 - 0.372	0.875		0.632	0.647	0.107	0.046 +0.003 -0.000	0.922 ±0.003	87- W
4	0.373 - 0.494	1.125		0.884	0.899	0.132	0.056 +0.004 -0.000	1.197 ±0.004	112- W
5	0.495 - 0.634	1.375		1.060	1.075	0.132	0.056 +0.004 -0.000	1.450 ±0.004	137- W
6	0.635 - 0.779	1.625		1.290	1.305	0.161	0.068 +0.004 -0.000	1.715 ±0.005	162- W
7	0.780 - 0.934	1.875		1.656	1.671	0.161	0.068 +0.004 -0.000	1.975 ±0.005	187- W
8	0.935 - 1.120	2.250		1.747	1.762	0.179	0.086 +0.005 -0.000	2.370 ±0.006	225- W

* Other flat or spiral-type retaining rings of suitable material are acceptable. The groove (E, F) should be dimensioned to fit the particular ring selected.

2.4.2 PACKING

To ensure proper sealing action, it is important that the following conditions be met, insofar as the Packing is concerned:

(1) The Packing must be solid rubber, with no air cells, cork or other compressible materials included; and (2) The Packing must be an interference fit both with the housing wall and the cable.

- A) **Packing Material.** The Packing should be of synthetic rubber compound, preferably neoprene, with a hardness of 35 ± 5 durometer. Other physical properties should correspond to those of MIL-R-3065, Grade SC 310 (ASTM Grade SC 310).

If the seal is to be used between bare electrical conductors or a shield and a conductive housing, the seal packing should be of chlorinated butyl or some other suitable non-conductive elastomer of 35 ± 5 durometer hardness.

- B) **Packing Surfaces.** Must be smooth and free of breaks or other imperfections. Surfaces in Figure 2-3 below marked

✓ = Molded Finish 63/ .

- C) **Packing Dimensions.** See Figure 2-4 and Table 2-2, below. The packing dimensions remain constant whether or not the optional boot is used.

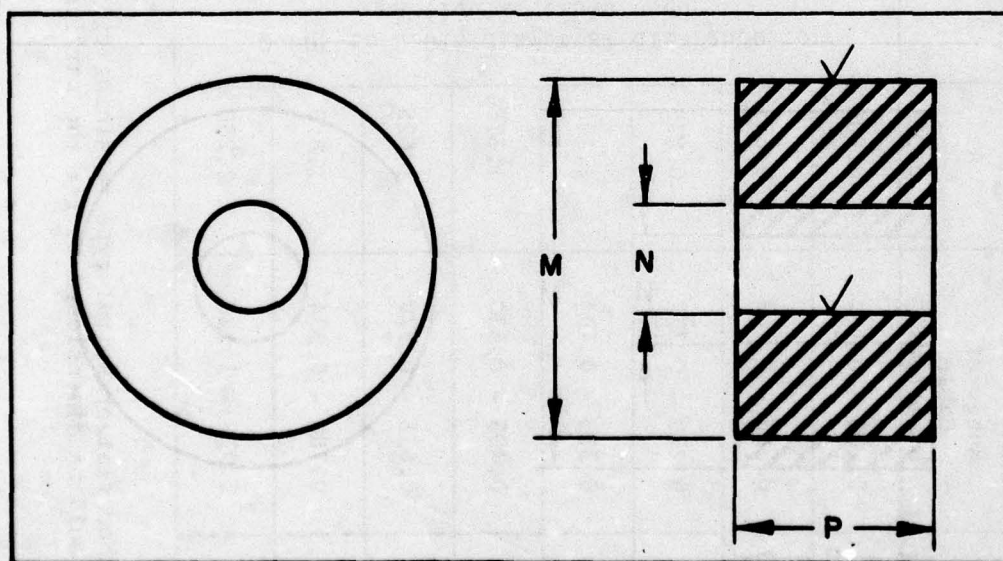


Figure 2-4. Packing

Table 2-2. Packing Dimensions (in.)

Seal No.	Range of Cable Diameters	M ± 0.015	N ± 0.015	P + 0.000 - 0.020
1	0.100 - 0.184	0.530	0.063	0.250
2	0.185 - 0.269	0.655	0.125	0.250
3	0.270 - 0.372	0.905	0.188	0.375
4	0.373 - 0.494	1.155	0.233	0.500
5	0.495 - 0.634	1.405	0.375	0.625
6	0.635 - 0.779	1.670	0.500	0.750
7	0.780 - 0.934	1.935	0.563	1.000
8	0.935 - 1.120	2.310	0.688	1.000

2.4.3 RETAINING WASHER (SEAL W/O BOOT)

This section and the section which follows give specifications for two Retaining Washers. The washer specified in this section is designed for the seal without the optional boot. It is of greater thickness and has a radius on the outside edge of its inner diameter to prevent cable wear.

- A) Retaining Washer Materials. The Retaining Washer can be of any material, compatible with the housing, such as corrosion resisting steel, brass, Teflon or nylon, with suitable resistance to corrosion and with rigidity sufficient to retain the other parts in place.
- B) Dimensions. See Figure 2-5 and Table 2-3, below. The Retaining Washer for the booted seal follows this section.

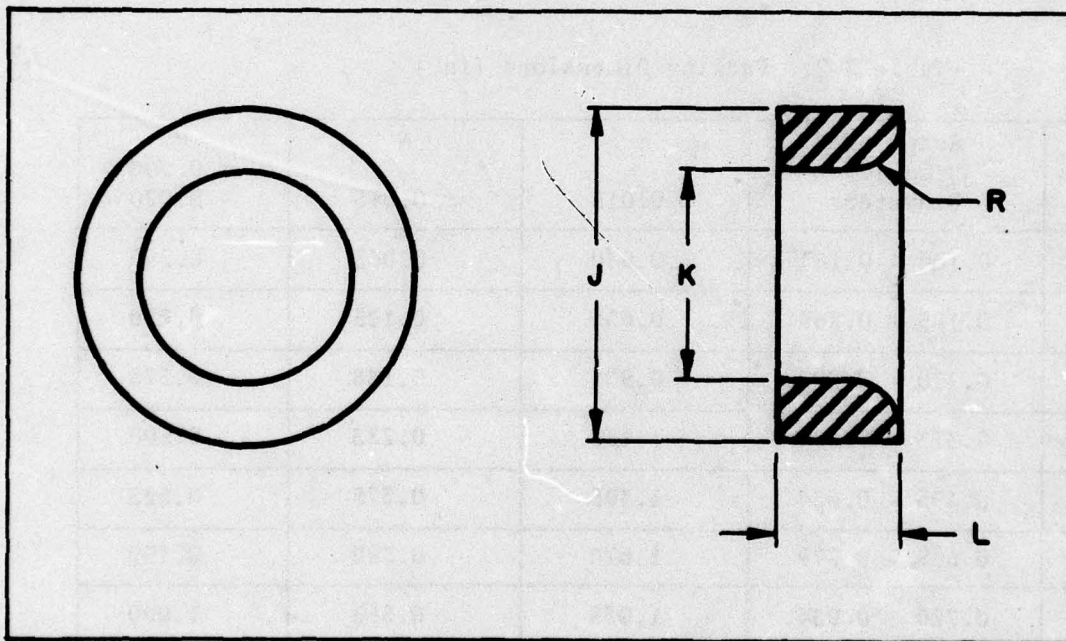


Figure 2-5. Retaining Washer (Seal W/O Boot)

Table 2-3. Retaining Washer Dimensions
(Seal W/O Boot) (in.)

Seal No.	Range of Cable Diameter	J ± 0.005	K	L ± 0.005	R ± 0.015
-1	0.100 - 0.184	0.470	0.005 to 0.015 diametral clearance for particular cable used	0.100	0.062
-2	0.185 - 0.269	0.470		0.100	0.062
-3	0.270 - 0.372	0.617		0.100	0.062
-4	0.373 - 0.494	0.869		0.175	0.093
-5	0.495 - 0.634	1.045		0.195	0.125
-6	0.635 - 0.779	1.275		0.235	0.187
-7	0.780 - 0.934	1.641		0.235	0.187
-8	0.935 - 1.120	1.732		0.300	0.250

2.4.4 RETAINING WASHER (SEAL WITH OPTIONAL BOOT)

A) Materials. Same as for section 2.4.3.

B) Dimensions. See Figure 2-6 and Table 2-4, below.

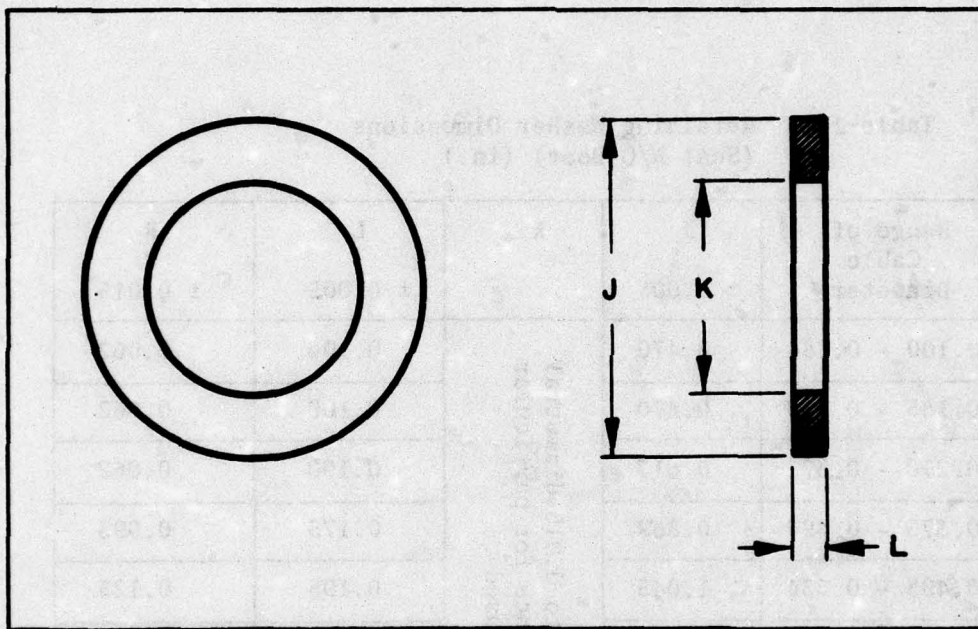


Figure 2-6. Retaining Washer (Seal with Boot)

Table 2-4. Retaining Washer Dimensions
(Seal with Boot) (in.)

Seal No.	Range of Cable Diameters	J ± 0.005	K	L ± 0.005
-1	0.100 - 0.184	0.490	0.005 to 0.015 diametral clearance for particular cable used	0.063
-2	0.185 - 0.269	0.615		0.063
-3	0.270 - 0.372	0.865		0.063
-4	0.373 - 0.494	1.115		0.125
-5	0.495 - 0.634	1.365		0.125
-6	0.635 - 0.779	1.615		0.188
-7	0.780 - 0.934	1.865		0.188
-8	0.935 - 1.120	2.240		0.250

2.4.5 BOOT (OPTIONAL)

- A) **Boot Material.** The Boot should be constructed from synthetic rubber compound of 50 ± 5 durometer hardness, such as ASTM Grade SC 520 (MIL-R-3065, Grade SC 520).
- B) **Boot Dimensions.** See Figure 2-7 and Table 2-5, below.

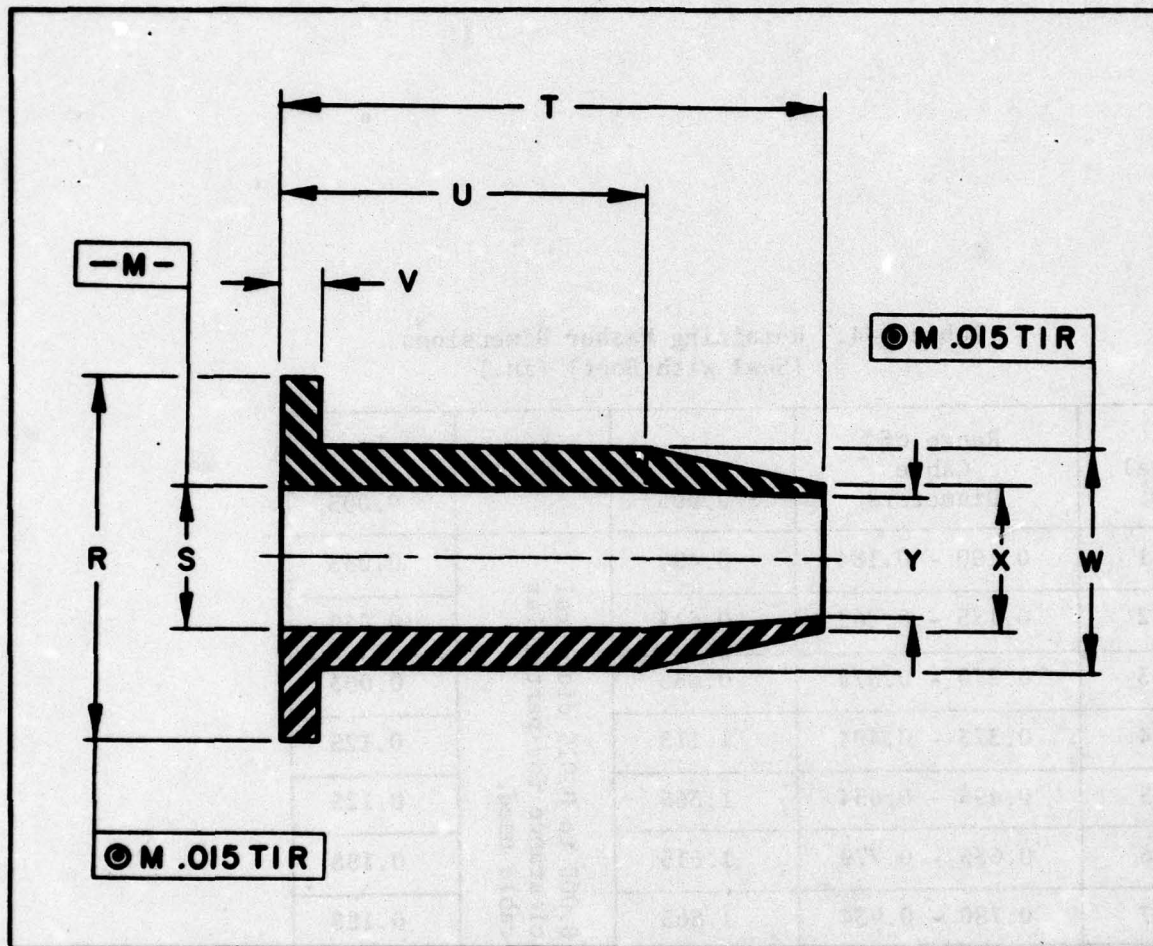


Figure 2-7. Boot

Table 2-5. Boot Dimensions (in.)

Seal No.	Range of Cable Diameters	R ±0.015	S ±0.015	T ±0.060	U ±0.060	V ±0.015	W ±0.015	X ±0.015	Y ±0.015
-1	0.100 - 0.184	0.450	0.150	0.875	0.625	0.063	0.275	0.150	0.094
-2	0.185 - 0.269	0.563	0.210	1.000	0.750	0.063	0.335	0.180	0.120
-3	0.270 - 0.372	0.813	0.315	1.250	0.875	0.063	0.440	0.270	0.200
-4	0.373 - 0.494	1.000	0.475	1.500	1.000	0.094	0.663	0.370	0.300
-5	0.495 - 0.634	1.300	0.530	1.625	1.125	0.125	0.718	0.480	0.400
-6	0.635 - 0.779	1.430	0.675	1.750	1.250	0.125	0.925	0.550	0.460
-7	0.780 - 0.934	1.750	0.800	2.000	1.500	0.125	1.050	0.780	0.660
-8	0.935 - 1.120	2.125	0.990	2.500	1.750	0.188	1.365	0.905	0.780

2.5 References

1. Morrison, James B., "O-rings and Interference Seals for Static Applications," Machine Design, February 7, 1957.

Table 2-1. Seal Dimensions (in.)

Seal No.	Seal Type	Seal Material	Seal Size (in.)	Seal Thickness (in.)	Seal Width (in.)	Seal Height (in.)	Seal Depth (in.)	Seal Length (in.)	Seal Weight (lb)
1	O-ring	Nitrile	1.00	0.10	1.00	0.10	0.10	1.00	0.05
2	O-ring	Nitrile	1.25	0.10	1.25	0.10	0.10	1.25	0.05
3	O-ring	Nitrile	1.50	0.10	1.50	0.10	0.10	1.50	0.05
4	O-ring	Nitrile	1.75	0.10	1.75	0.10	0.10	1.75	0.05
5	O-ring	Nitrile	2.00	0.10	2.00	0.10	0.10	2.00	0.05
6	O-ring	Nitrile	2.25	0.10	2.25	0.10	0.10	2.25	0.05
7	O-ring	Nitrile	2.50	0.10	2.50	0.10	0.10	2.50	0.05
8	O-ring	Nitrile	2.75	0.10	2.75	0.10	0.10	2.75	0.05
9	O-ring	Nitrile	3.00	0.10	3.00	0.10	0.10	3.00	0.05
10	O-ring	Nitrile	3.25	0.10	3.25	0.10	0.10	3.25	0.05
11	O-ring	Nitrile	3.50	0.10	3.50	0.10	0.10	3.50	0.05
12	O-ring	Nitrile	3.75	0.10	3.75	0.10	0.10	3.75	0.05
13	O-ring	Nitrile	4.00	0.10	4.00	0.10	0.10	4.00	0.05
14	O-ring	Nitrile	4.25	0.10	4.25	0.10	0.10	4.25	0.05
15	O-ring	Nitrile	4.50	0.10	4.50	0.10	0.10	4.50	0.05
16	O-ring	Nitrile	4.75	0.10	4.75	0.10	0.10	4.75	0.05
17	O-ring	Nitrile	5.00	0.10	5.00	0.10	0.10	5.00	0.05
18	O-ring	Nitrile	5.25	0.10	5.25	0.10	0.10	5.25	0.05
19	O-ring	Nitrile	5.50	0.10	5.50	0.10	0.10	5.50	0.05
20	O-ring	Nitrile	5.75	0.10	5.75	0.10	0.10	5.75	0.05
21	O-ring	Nitrile	6.00	0.10	6.00	0.10	0.10	6.00	0.05
22	O-ring	Nitrile	6.25	0.10	6.25	0.10	0.10	6.25	0.05
23	O-ring	Nitrile	6.50	0.10	6.50	0.10	0.10	6.50	0.05
24	O-ring	Nitrile	6.75	0.10	6.75	0.10	0.10	6.75	0.05
25	O-ring	Nitrile	7.00	0.10	7.00	0.10	0.10	7.00	0.05
26	O-ring	Nitrile	7.25	0.10	7.25	0.10	0.10	7.25	0.05
27	O-ring	Nitrile	7.50	0.10	7.50	0.10	0.10	7.50	0.05
28	O-ring	Nitrile	7.75	0.10	7.75	0.10	0.10	7.75	0.05
29	O-ring	Nitrile	8.00	0.10	8.00	0.10	0.10	8.00	0.05
30	O-ring	Nitrile	8.25	0.10	8.25	0.10	0.10	8.25	0.05
31	O-ring	Nitrile	8.50	0.10	8.50	0.10	0.10	8.50	0.05
32	O-ring	Nitrile	8.75	0.10	8.75	0.10	0.10	8.75	0.05
33	O-ring	Nitrile	9.00	0.10	9.00	0.10	0.10	9.00	0.05
34	O-ring	Nitrile	9.25	0.10	9.25	0.10	0.10	9.25	0.05
35	O-ring	Nitrile	9.50	0.10	9.50	0.10	0.10	9.50	0.05
36	O-ring	Nitrile	9.75	0.10	9.75	0.10	0.10	9.75	0.05
37	O-ring	Nitrile	10.00	0.10	10.00	0.10	0.10	10.00	0.05
38	O-ring	Nitrile	10.25	0.10	10.25	0.10	0.10	10.25	0.05
39	O-ring	Nitrile	10.50	0.10	10.50	0.10	0.10	10.50	0.05
40	O-ring	Nitrile	10.75	0.10	10.75	0.10	0.10	10.75	0.05
41	O-ring	Nitrile	11.00	0.10	11.00	0.10	0.10	11.00	0.05
42	O-ring	Nitrile	11.25	0.10	11.25	0.10	0.10	11.25	0.05
43	O-ring	Nitrile	11.50	0.10	11.50	0.10	0.10	11.50	0.05
44	O-ring	Nitrile	11.75	0.10	11.75	0.10	0.10	11.75	0.05
45	O-ring	Nitrile	12.00	0.10	12.00	0.10	0.10	12.00	0.05
46	O-ring	Nitrile	12.25	0.10	12.25	0.10	0.10	12.25	0.05
47	O-ring	Nitrile	12.50	0.10	12.50	0.10	0.10	12.50	0.05
48	O-ring	Nitrile	12.75	0.10	12.75	0.10	0.10	12.75	0.05
49	O-ring	Nitrile	13.00	0.10	13.00	0.10	0.10	13.00	0.05
50	O-ring	Nitrile	13.25	0.10	13.25	0.10	0.10	13.25	0.05
51	O-ring	Nitrile	13.50	0.10	13.50	0.10	0.10	13.50	0.05
52	O-ring	Nitrile	13.75	0.10	13.75	0.10	0.10	13.75	0.05
53	O-ring	Nitrile	14.00	0.10	14.00	0.10	0.10	14.00	0.05
54	O-ring	Nitrile	14.25	0.10	14.25	0.10	0.10	14.25	0.05
55	O-ring	Nitrile	14.50	0.10	14.50	0.10	0.10	14.50	0.05
56	O-ring	Nitrile	14.75	0.10	14.75	0.10	0.10	14.75	0.05
57	O-ring	Nitrile	15.00	0.10	15.00	0.10	0.10	15.00	0.05
58	O-ring	Nitrile	15.25	0.10	15.25	0.10	0.10	15.25	0.05
59	O-ring	Nitrile	15.50	0.10	15.50	0.10	0.10	15.50	0.05
60	O-ring	Nitrile	15.75	0.10	15.75	0.10	0.10	15.75	0.05
61	O-ring	Nitrile	16.00	0.10	16.00	0.10	0.10	16.00	0.05
62	O-ring	Nitrile	16.25	0.10	16.25	0.10	0.10	16.25	0.05
63	O-ring	Nitrile	16.50	0.10	16.50	0.10	0.10	16.50	0.05
64	O-ring	Nitrile	16.75	0.10	16.75	0.10	0.10	16.75	0.05
65	O-ring	Nitrile	17.00	0.10	17.00	0.10	0.10	17.00	0.05
66	O-ring	Nitrile	17.25	0.10	17.25	0.10	0.10	17.25	0.05
67	O-ring	Nitrile	17.50	0.10	17.50	0.10	0.10	17.50	0.05
68	O-ring	Nitrile	17.75	0.10	17.75	0.10	0.10	17.75	0.05
69	O-ring	Nitrile	18.00	0.10	18.00	0.10	0.10	18.00	0.05
70	O-ring	Nitrile	18.25	0.10	18.25	0.10	0.10	18.25	0.05
71	O-ring	Nitrile	18.50	0.10	18.50	0.10	0.10	18.50	0.05
72	O-ring	Nitrile	18.75	0.10	18.75	0.10	0.10	18.75	0.05
73	O-ring	Nitrile	19.00	0.10	19.00	0.10	0.10	19.00	0.05
74	O-ring	Nitrile	19.25	0.10	19.25	0.10	0.10	19.25	0.05
75	O-ring	Nitrile	19.50	0.10	19.50	0.10	0.10	19.50	0.05
76	O-ring	Nitrile	19.75	0.10	19.75	0.10	0.10	19.75	0.05
77	O-ring	Nitrile	20.00	0.10	20.00	0.10	0.10	20.00	0.05
78	O-ring	Nitrile	20.25	0.10	20.25	0.10	0.10	20.25	0.05
79	O-ring	Nitrile	20.50	0.10	20.50	0.10	0.10	20.50	0.05
80	O-ring	Nitrile	20.75	0.10	20.75	0.10	0.10	20.75	0.05
81	O-ring	Nitrile	21.00	0.10	21.00	0.10	0.10	21.00	0.05
82	O-ring	Nitrile	21.25	0.10	21.25	0.10	0.10	21.25	0.05
83	O-ring	Nitrile	21.50	0.10	21.50	0.10	0.10	21.50	0.05
84	O-ring	Nitrile	21.75	0.10	21.75	0.10	0.10	21.75	0.05
85	O-ring	Nitrile	22.00	0.10	22.00	0.10	0.10	22.00	0.05
86	O-ring	Nitrile	22.25	0.10	22.25	0.10	0.10	22.25	0.05
87	O-ring	Nitrile	22.50	0.10	22.50	0.10	0.10	22.50	0.05
88	O-ring	Nitrile	22.75	0.10	22.75	0.10	0.10	22.75	0.05
89	O-ring	Nitrile	23.00	0.10	23.00	0.10	0.10	23.00	0.05
90	O-ring	Nitrile	23.25	0.10	23.25	0.10	0.10	23.25	0.05
91	O-ring	Nitrile	23.50	0.10	23.50	0.10	0.10	23.50	0.05
92	O-ring	Nitrile	23.75	0.10	23.75	0.10	0.10	23.75	0.05
93	O-ring	Nitrile	24.00	0.10	24.00	0.10	0.10	24.00	0.05
94	O-ring	Nitrile	24.25	0.10	24.25	0.10	0.10	24.25	0.05
95	O-ring	Nitrile	24.50	0.10	24.50	0.10	0.10	24.50	0.05
96	O-ring	Nitrile	24.75	0.10	24.75	0.10	0.10	24.75	0.05
97	O-ring	Nitrile	25.00	0.10	25.00	0.10	0.10	25.00	0.05
98	O-ring	Nitrile	25.25	0.10	25.25	0.10	0.10	25.25	0.05
99	O-ring	Nitrile	25.50	0.10	25.50	0.10	0.10	25.50	0.05
100	O-ring	Nitrile	25.75	0.10	25.75	0.10	0.10	25.75	0.05

Section 3

TABLE OF CONTENTS

<u>Section</u>	<u>Title</u>	<u>Page</u>
3.1	Introduction	3-1
3.1.1	Scope	3-2
3.1.2	Principle of Operation	3-2
3.1.2.1	Seal Support	3-3
3.1.2.2	Additional Design Possibilities	3-4
3.2	Cable Specifications and Sources	3-5
3.2.1	Cable Splicing	3-6
3.3	General Description	3-10
3.3.1	Parts List	3-14
3.4	Assembly Procedure	3-15
3.5	Design Specifications--Materials and Dimensions	3-24

Section 3

LIST OF FIGURES

<u>Figure</u>	<u>Title</u>	<u>Page</u>
3-1	Autec Cable--General Specifications	3-7
3-2	Condex Cable--General Specifications	3-8
3-3	U.S.S. 2Q90XCR--Dimensions	3-9
3-4	Upper and Lower Seal and Washer Assembly	3-10
3-5	Cable Seal and Repeater Housing Assembly	3-11
3-6	Cable Stripping Unit	3-16
3-7	Removing Polyethylene Strips from Inner Sheath	3-17
3-8	Strain Wire and Nicopress Fitting Arrangement	3-18
3-9	Micarta Spacing Fork and Aluminum Cup Mold	3-19
3-10	Potted Strain Wires	3-20
3-11	Bell Fitting of Vacuum Pump	3-22
3-12	Cap and Fairlead: 1-(X)	3-26
3-13	Cable Seal Housing: 2	3-28
3-14	Spacer: 3-(X)	3-29
3-15	Seal Washer: 4-(X)	3-30
3-16	Backup Washer: 5-(X)	3-31
3-17	Thrust Washer: 6-(X)	3-32
3-18	Tension Washer: 8-(X)	3-33
3-19	Sleeve, Torque Resisting Pins: 10	3-34
3-20	Cup: 11-(X)	3-35
3-21	Torque Washer: 12-(X)	3-36
3-22	Inner Jacket Seal: 13-(X)	3-37
3-23	Backup Washer: 14-(X)	3-38

<u>Figure</u>	<u>Title</u>	<u>Page</u>
3-24	Insulator Cup: 15-(X)	3-39
3-25	Shield Pin: 16-(X)	3-40
3-26	Middle Backup Washer: 17-(X)	3-41
3-27	Middle Seal: 18-(X)	3-42
3-28	Inner Pressure Washer: 19	3-43
3-29	Inner Seal: 20	3-44
3-30	Lower Pressure Washer: 21-(X)	3-45
3-31	Thrust Washer: 22	3-46
3-32	Center Pin: 23	3-47
3-33	Main Nut: 24	3-48
3-34	Spacer: 27	3-49
3-35	Electronics Housing: 29	3-51
3-36	Keyed Spacer: 30	3-52
3-37	Collar: 31	3-53
3-38	Junction Housing (Optional): 23	3-55
3-39	Pressure Cap: 34	3-57

Section 3

LIST OF TABLES

<u>Table</u>	<u>Title</u>	<u>Page</u>
3-1	Coaxial Submarine Cables	3-5
3-2	Cable Manufacturers	3-6
3-3	Parts List for Cable Seal and Repeater Housing Assembly	3-12

Section 3

STANDARD FOR AN INTERFERENCE CABLE SEAL AND REPEATER HOUSING ASSEMBLY

3.1 Introduction

This standard establishes dimensions and materials for components of a multi-level coaxial submarine cable seal which was developed at the Applied Physics Laboratory at the University of Washington. The complete assembly is made up of two discrete seal assemblies, each utilizing a stack of interference seals, joined together by a mid-section which is either an electronics housing or a simple junction housing.

The entire assembly is designed to meet the demanding requirements for low-maintenance cable seals intended for long-term submersion at substantial ocean depths. The assembly specified here was designed to seal a coaxial submarine cable for a duration of 20 years at depths of up to 7,000 feet (additional testing would be required for greater depths--see Section 3.1.2.2). While the seal might be applied to any type of coaxial submarine cable, it was intended primarily for instrumentation and communication lines.

Due to the specific design of the Cable Seal and Repeater Housing Assembly, which utilizes two independent seal assemblies joined by a middle housing section (see Figure 3-5), the application may also be used as a field splice to join two lengths of either the same cable or different kinds of cable. When this kind of application is intended a Junction Housing is used in place of the Electronics Housing as the mid-section. While the factory type of cable splice is preferable, it may not always be practical due to time limitations and other contingencies. The Cable Seal and Repeater Housing Assembly is designed to be as reliable as a factory splice. While it is bulkier than a factory splice, it has a considerable advantage in that it may be made-up on shipboard in the relatively short period of 2 hours, once the technique has been learned.

3.1.1 SCOPE

The Cable Seal and Repeater Housing Assembly described and specified in this manual section is both a cable termination and a field splicing device. In addition, it has the capability to house a repeater amplifier in the Electronics Housing which is situated between the two seals of the assembly. Utilizing a stack of interference seals of several materials and sizes, it is designed for a low-maintenance, 20-year duration, and for depths of up to 7,000 feet or approximately 3,000 psi. This standard establishes materials and dimensions for the seal components which may be applied to any of three coaxial submarine cables. These include the Autec, Condex and U.S. Steel cables identified in Section 3.2, below. Anti-rotation and anti-extrusion devices are integrated into the seal design. All materials and dimensions have been carefully tested and it is essential that the specifications given in this manual be followed if the seal is to operate properly.

3.1.2 PRINCIPLE OF OPERATION

The basic principle of multi-level interference seal action is identical to that of the simple interference seal or the O-ring. A cable is passed through a rubber packing of interference fit, thus establishing an initial radial pressure between the cable and packing which remains in constant excess of additional pressures generated by increased ocean depth. A similar initial pressure is established by the interference fit of the seal with its housing, thus blocking the alternate leakage path in an identical fashion. (See Section 1.4 for theoretical discussion.)

The multi-level interference seal provides a double or series seal for every layer of a given cable to prevent leakage or hosing into the inner electronics in the event of a cut at any depth whatever in the cable. The series seal is installed at every sealing point, including those utilizing the standard O-ring, to provide the highly reliable redundant seals.

The center conductor will continue to operate even when a cut occurs to the depth of the return conductor or shield, allowing power to be transmitted down and back again until the damage is repaired.

The assembly also seals the inner electronics housing in the event of a complete shear, either in the cable or in the seal assembly itself.

3.1.2.1 Seal Support. The somewhat more complicated design of the multi-level interference seal is due partially to the need to support of the soft rubber seals which tend to extrude under substantial pressures. The seal washers of the upper housing area (See Part No. 4, Figure 3-5) are constructed from soft 35 durometer rubber which, because of its softness, has excellent sealing properties. Under pressures of more than 1000 psi, however, the soft rubber will begin to extrude into spaces downstream in the housing assembly, thereby diminishing the volume and effectiveness of the seal. For this reason, a backup washer of a firmer 70 durometer rubber is positioned directly beneath the primary seals to provide support and to fill any gaps along the cable immediately below the primary seals.

The pressure forces in the lower housing assembly beneath the Cerrobend Cup (Part No. 11, Figure 3-5) are both downstream and upstream and the soft rubber seals have been found to require support both above and below.

The two Inner Jacket Seals (Part No. 13, Figure 3-5) situated immediately beneath the Cerrobend Cup may extrude upward into the air space but are prevented from further upward extrusion by the Cerrobend potting around the cable immediately above them. On the downstream side they are supported by a backup washer of Teflon. The cold flow characteristics of Teflon are such that at about 1000 psi it will begin to flow out and fill the gaps left by its clearance fit with the cable and provide the required support for the softer rubber seal.

Teflon washers are used similarly for backup support of either side of the middle and inner seal pairs (Part Nos. 18 and 20, Figure 3-5).

The Cable Seal and Repeater Housing Assembly has been tested to a lower limit of 14,000 feet; it is therefore recommended for applications of up to 7,000 feet. Whether or not the Teflon backup support is adequate for any depth beyond 7,000 feet is not known.

3.1.2.2 Additional Design Possibilities. At depths of less than 2,000 feet, Teflon washers are not required and may be replaced with hard rubber washers of 70 durometer. At depths of from 2,000 to 7,000 feet, the Teflon backup washers are required.

While the Teflon washers may be adequate for much greater depths, additional testing would be required to establish this. Should such testing prove the Teflon to provide inadequate support against seal extrusion, at greater depths than 7,000 feet, additional support washers could be constructed from lead to provide backup support for the Teflon washers. Such a seal design would be based on the fact that lead, like Teflon, is essentially incompressible, and will cold flow at substantially higher pressures. The theory behind the use of lead for seal support at great pressures is not new and has been examined by Bridgman in his work with extremely high pressure seals (see Reference 1, Section 1.7).

Lead washers for the Seal Assembly would be situated so as to provide backup support for each Teflon washer, either upstream or downstream, depending upon whether the Teflon washer itself is upstream or downstream with regard to the soft rubber packing it is supporting. The lead washers would be of approximately the same dimensions as the Teflon washers. Where insulation was required between the lead washer and the center conductor, the lead washer would be chambered to permit the insertion of a Teflon insulating sleeve. Once such a sealing design was fully worked out and tested, it would very likely be effective at any ocean depth whatever.

3.2 Cable Specifications and Sources

The Cable Seal and Repeater Housing Assembly has been used with three types of coaxial submarine cable to date. These include the Autec, Condex and U.S. Steel cables, as listed in Table 3-1, and as shown in Figures 3-1, 3-2, and 3-3, below. The seal is not limited to use with these cables; however, the design drawings of this manual section meet the specific requirements for the construction, dimensions and materials of the Autec, Condex and U.S. Steel cables identified. Note that the cable specifications listed in Figures 3-1, 3-2, and 3-3, are only for purposes of identifying the cable dimensions appropriate to the parts dimensions of the seal, as specified in Section 3.5, below. The most recent cable specifications, or the complete specifications of the cables listed here, should be secured at the manufacturer sources which are listed in Table 3-2, below. Minor diametral variations in cable dimensions may be accommodated with proportionate diametral variations in the seal component specifications of section 3.5, below.

Table 3-1. Coaxial Submarine Cables

Assembly Dash No.	Cable Unit	Documentation Source	
-1	Autec*	Keyport Sketch NTS No. 7356	Figure 2-1
-2	Condex	Condex Corp. Drawing No. 1260	Figure 2-2
-3	U.S. Steel	Spec. for Type 2Q90XCR	Figure 2-3

* Conforms to Simplex Range Cable 0.057"/0.180".

Each of the cables listed was chosen for the low resistivity of the central conductor, long-term durability and the expense of its manufacture. Suggested sources of supply are listed below. The manufacturers are either presently supplying the cable or have indicated that they have the continued capability to produce the cable on order. In addition, the suppliers will furnish additional specifications for their respective cables upon inquiry. The Naval Torpedo Station at Keyport, Washington, has used the Simplex range cable extensively and found it to be very satisfactory. They are presently purchasing the same cable from ITT, however. APL has used all three cables on the St. Croix range.

Table 3-2. Cable Manufacturers

A u t e c	Simplex Wire and Cable Co. HydroSpace Systems Division Portsmouth, N.H. 03801 (603) 436-6100
	ITT Cable-HydroSpace P.O. Box 81446 San Diego, Calif. 92138 (714) 474-6341
C o n d e x	Condex Corporation Point and Erie Streets Camden, N.J. 08102 (609) 966-0915
U S S	U.S. Steel Electrical Cable Division Ballard Street Worcester, Mass. 01607 (617) 752-6711

3.2.1 CABLE SPLICING

The Cable Seal Assembly, with its independent sealing units connected by a middle Junction Housing (see Table 3-3, Part No. 33), may be used as a splice between two different kinds of cable. Thus the Autec, Condex or U.S. Steel cables may be spliced together as desired into a single line application.

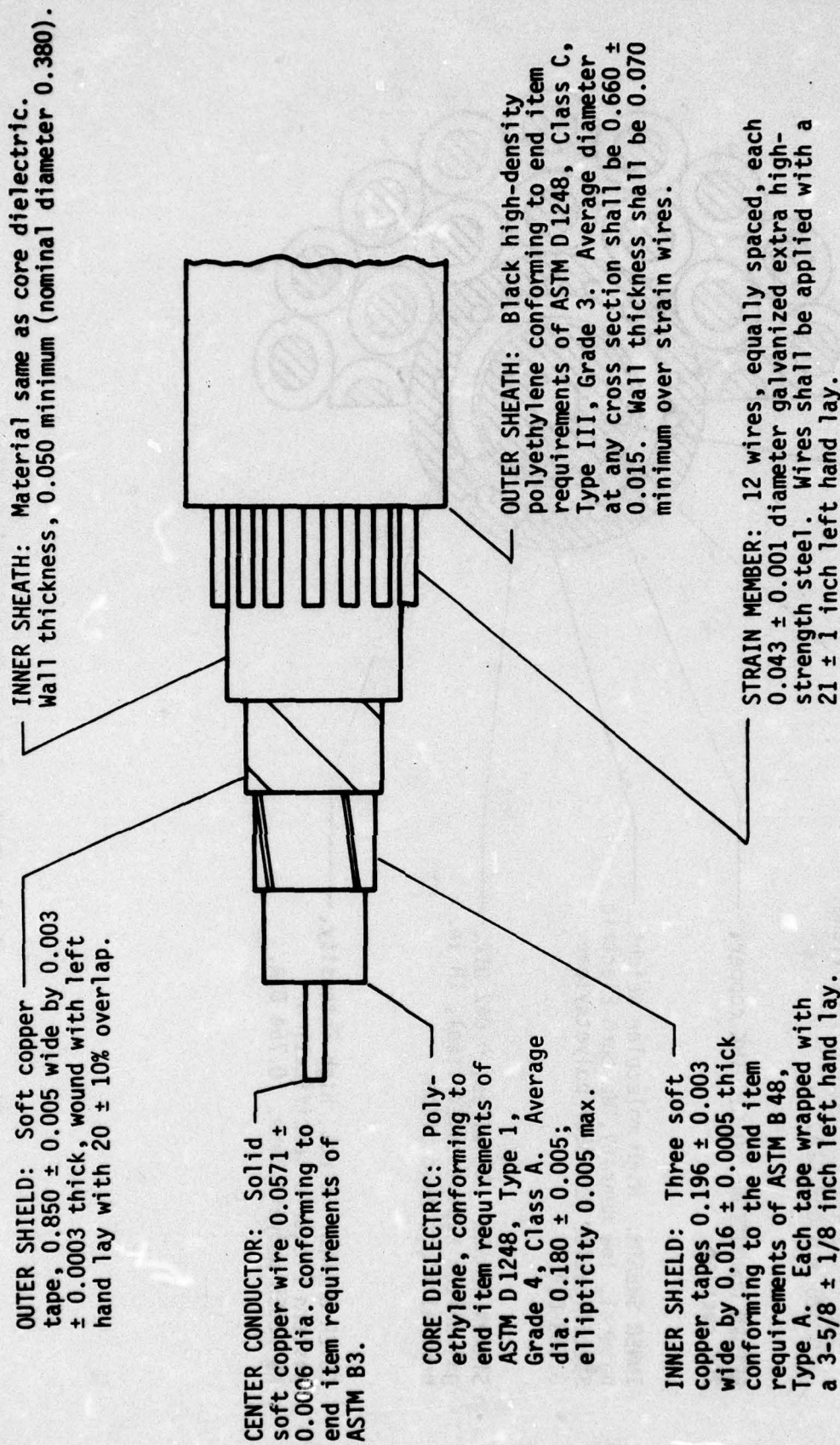


Figure 3-1. Autec Cable, General Specifications (in.)

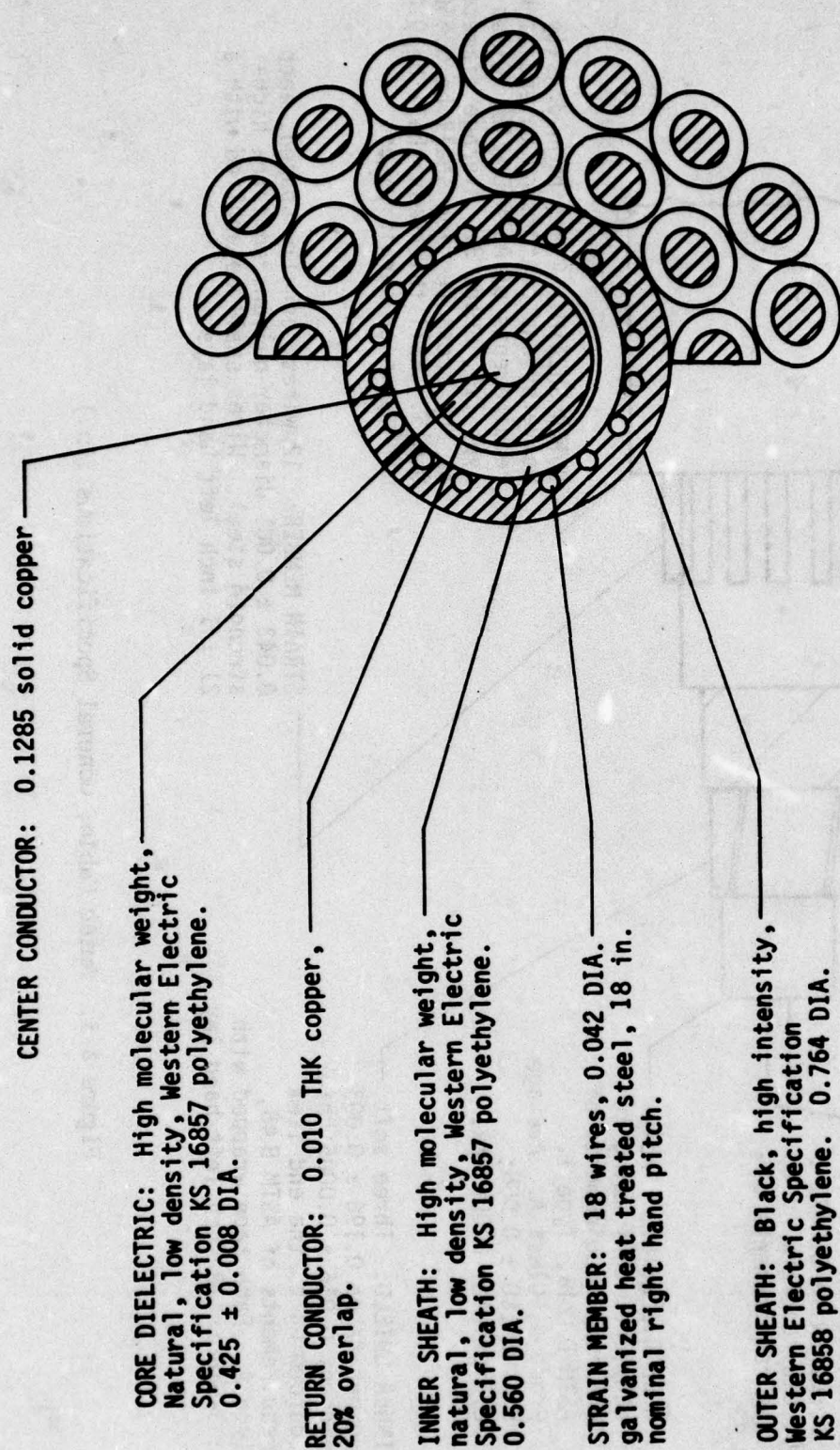


Figure 3.2. Condex Cable, General Specifications (in.)

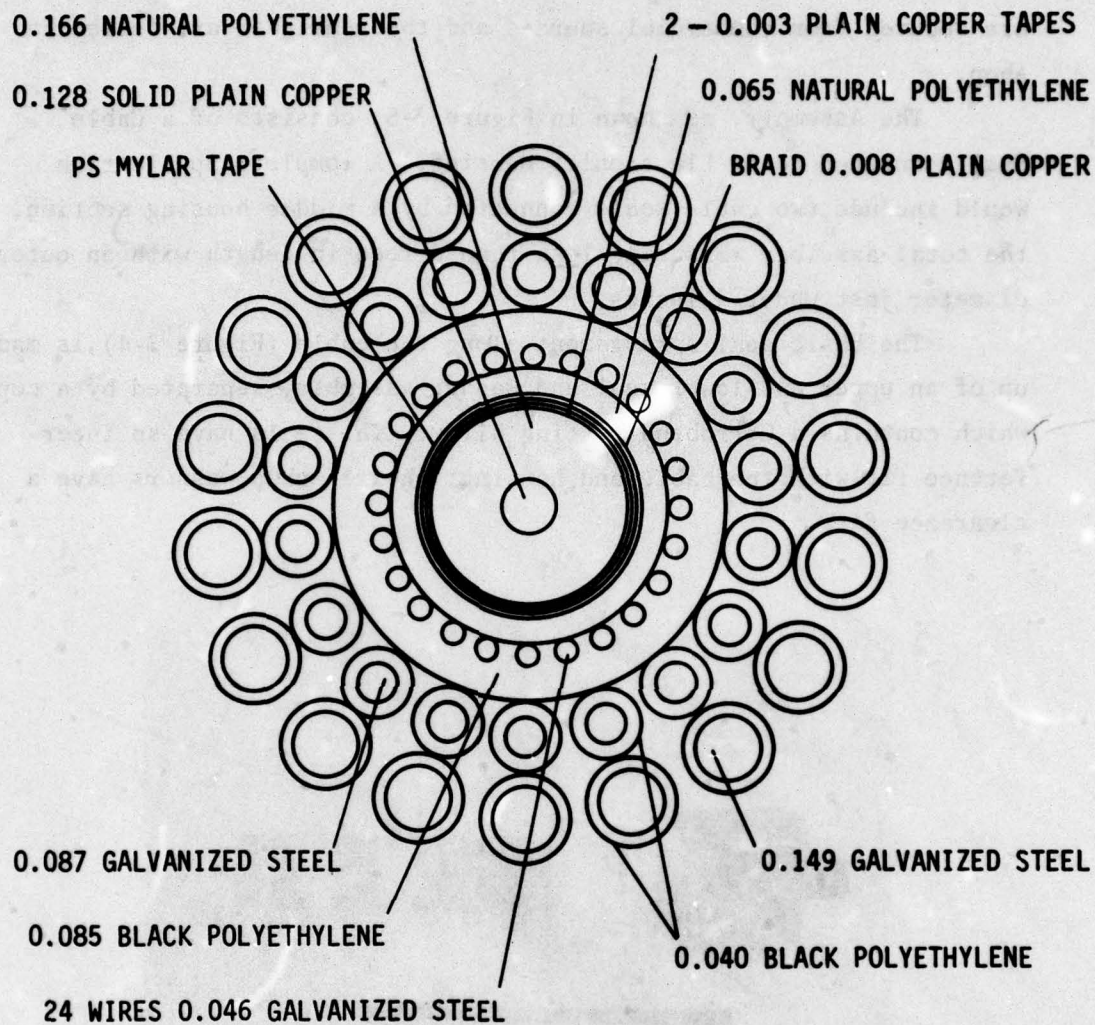


Figure 3-3. U.S.S. 2Q90XCR, Dimensions (in.),
Including Shore Armor

3.3 General Description

The basic seal design, including the Electronics Housing and its components, consists of 32 specific kinds of parts. Six of these are secured from commercial sources and the remainder are tooled in shop.

The Assembly, as shown in Figure 3-5, consists of a Cable Seal connected to an Electronics Housing. A complete application would include two cable seals connected by a middle housing section, the total assembly measuring less than 3 feet in length with an outer diameter just under 4 inches.

The basic seal arrangement along the cable (Figure 3-4) is made up of an upper and lower seal and washer assembly, separated by a cup which contains a Cerrobend potting alloy. The seals have an interference fit with the cable and housing; their backup washers have a clearance fit.

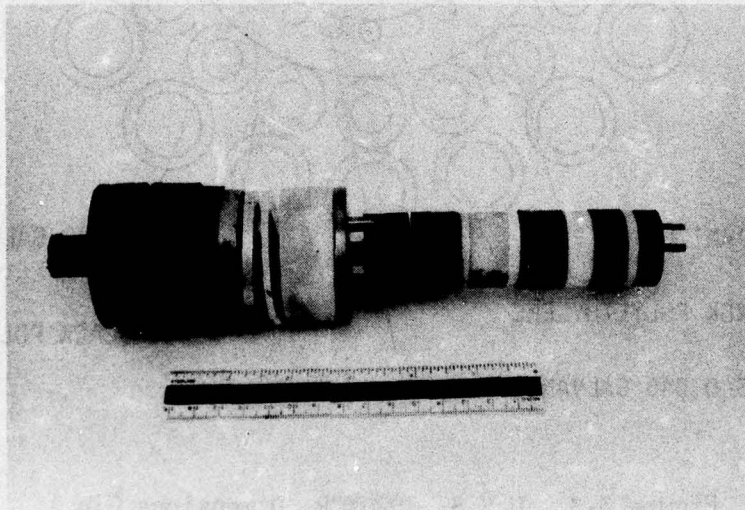


Figure 3-4. Upper and Lower Seal and Washer Assembly

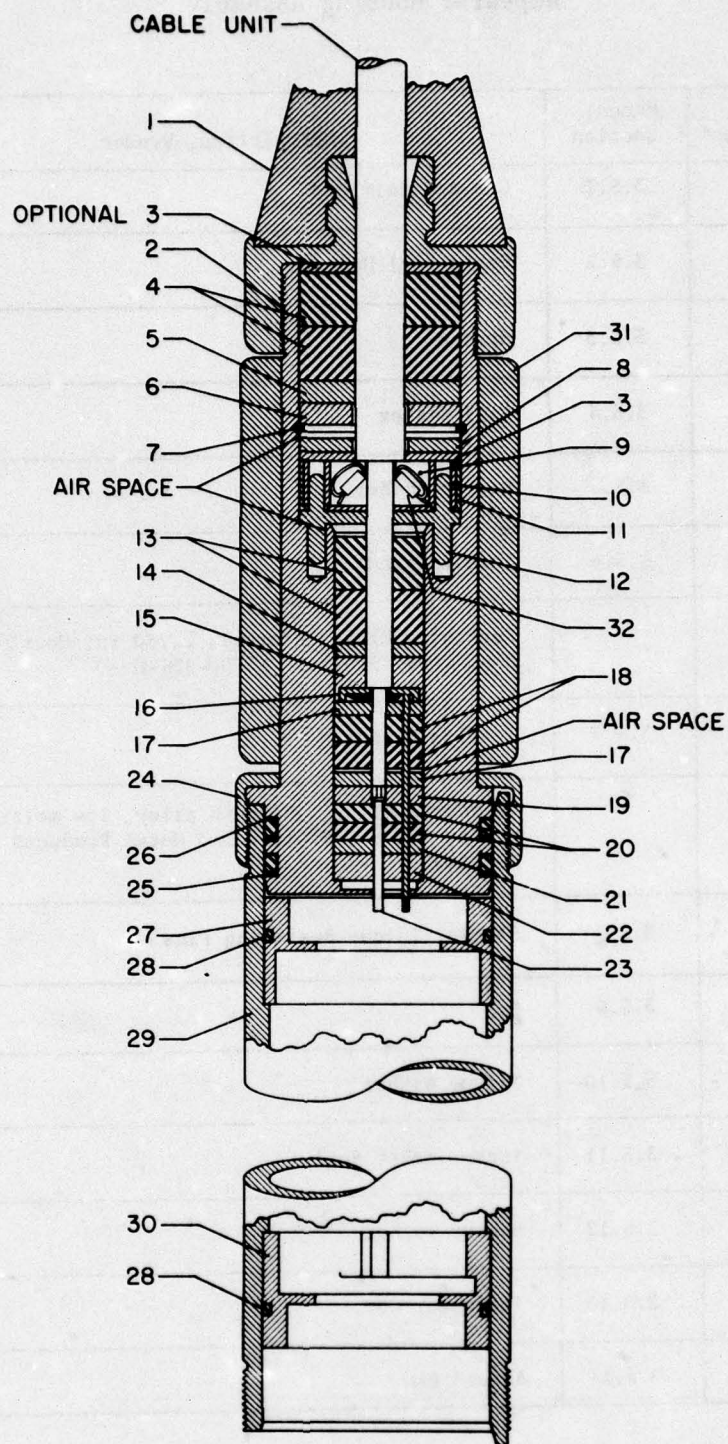


Figure 3-5. Cable Seal and Repeater Housing Assembly. Parts numbers correspond to those of Table 3-3, which follows.

Table 3-3. Parts List for Cable Seal and Repeater Housing Assembly

Part No.*	Qty.	Manual Section	Description, Vendor
1-(X)	1	3.5.1	Cap and Fairlead
2	1	3.5.2	Cable Seal Housing
3-(X)	2	3.5.3	Spacer
4-(X)	2	3.5.4	Seal Washer
5-(X)	.1	3.5.5	Backup Washer
6-(X)	1	3.5.6	Thrust Washer
7	1		Retaining Ring, Internal, 2.250 in. Housing Dia. Cres. Truarc: N5000-225-H
8-(X)	1	3.5.7	Tension Washer
9	AR		Cerrobend Alloy: Bismuth alloy, low melting point, 158°F (70°C), Cerro Metal Products Division
10	2	3.5.8	Sleeve, Torque Resisting Pins
11-(X)	1	3.5.9	Cup
12-(X)	1	3.5.10	Torque Washer
13-(X)	2	3.5.11	Inner Jacket Seal
14-(X)	1	3.5.12	Backup Washer
15-(X)	1	3.5.13	Insulator Cup
16-(X)	1	3.5.14	Shield Pin

*
 For Autec cable assemblies, substitute (-1) for the (-X).
 For Condex cable assemblies, substitute (-2) for the (-X).
 For U.S. Steel cable assemblies, substitute (-3) for the (-X).

Table 3-3, cont. Parts List for Cable Seal and Repeater Housing Assembly

Part No.	Qty.	Manual Section	Description, Vendor
17-(X)	2	3.5.15	Middle Backup Washer
18-(X)	2	3.5.16	Middle Seal
19	1	3.5.17	Inner Pressure Washer
20	2	3.5.18	Inner Seal
21	1	3.5.19	Lower Pressure Washer
22	1	3.5.20	Lower Thrust Washer
23	1	3.5.21	Center Pin
24	1	3.5.22	Main Nut
25	2		Backup Ring 2.768 in., ID, Parker Seal Co.: 8-335-N300-9
26	2		O-Ring, 2.725 in., ID, 0.210 in. Width (MS28775-335)
27	1	3.5.23	Spacer
28	2		O-Ring, 2.859 in., ID, 0.139 in. Width (AN6230-11)
29	1	3.5.24	Electronics Housing
30	1	3.5.25	Keyed Spacer
31	1	3.5.26	Collar
32			Nicopress Splicing Sleeve, 1/16 in., National Telephone Supply Co.: 18-1-C
33	1	3.5.27	Junction Housing (Alternate to Part Nos. 27, 28, 29 and 30)
34	1	3.5.28	Pressure Cap

3.3.1 PARTS LIST

The Parts List outlined in Table 3-3 identifies all required components for the Cable Seal and Repeater Housing Assembly. These include the following commercial items: the Retaining Ring (No. 7), the Cerrobend Alloy (No. 9), Backup Rings (No. 25), O-rings (Nos. 26 and 28), and the Nicopress Splicing Sleeves (No. 32).

- A) The dash (X) numbers given after certain part numbers pertain to the type of cable the seal is being applied to (see Table 3-1, above). Thus the dash one (-1) would replace the (-X) for assemblies involving Autec cable.

Components without dash numbers are standard for all three types of cable.

- B) The Delrin Spacer (No. 3) is optional, being used only when there is space within the Housing to accommodate it. If, when seated, its upstream face protrudes from the Housing, it is pulled out, snipped and removed.
- C) The Center Pin (No. 23) is used only with the Autec (-1) cable. The Condex and U.S. Steel cables have center conductors of sufficient diameter to dispense with the pin.
- D) The alternate Junction Housing (No. 33) is a substitute part for the Electronics Housing (No. 29) and the components of the Electronics Housing (Nos. 27, 28 and 30). It is used when the cable seal only is required, as, for example, in making a field splice.
- E) The Pressure Cap (No. 34) is used to protect the exposed end of the Electronics Housing or the Junction Housing.
- F) For additional tools and materials required during the assembly procedure, see Section 3.4, below.

3.4 Assembly Procedure

Once mastered, the entire assembly procedure for the two seals and center housing should take two men approximately two hours.

A) Preliminary Preparations.

1. Assemble and box the specified seal components which will be required for the assembly procedure (see Parts List, Table 3-3). Label the boxes for easy identification in the field. Be sure to include extra parts.
2. In addition, the following tools and materials will be required.
 - (1) Hot Plate, 1500 watt
 - (1) Soldering Gun, Heavy Duty, AC, 350 watt
 - (1) Cable Stripper (soldering unit with resistance hot tip)--See Figures 3-6, 3-7
 - (1) Heat Gun
 - (1) Vacuum Pump (equipped with bell fitting, neoprene gasket)--See Figure 3-11.
 - (4 Lg. Tubes) Dow-Corning (DC-55) Lubricant
 - (1) Hacksaw Frame
 - (Several) Hacksaw Blades
 - (1) Thread File, No. 1
 - (6) Bench Vises
 - (1) Cerrobend Cup Mold, Aluminum--See Figure 3-9
 - (1) Heat Tongs
 - (1) Double Boiler Pot
 - (1) Steel Beaker
 - (1 Tube) Epoxy Glue, 5 Min.
 - (2) Strap Wrenches, Rigid, No. 5
 - (1) Foam Pad on Stick (for applying DC-55 to lower seal housing)
 - (1) Piece of Plastic-coated Hookup Wire, 15 in.
 - (2) Micarta Spacer Forks, 1/4 in. and 1/16 in.
--See Figure 3-9
 - (6 cans) Freon Coolant
 - (1 Pt.) Acetone
 - Snap Ring Pliers
 - Electrical Tape, Shrink Tubing
 - Solder
 - Miscellaneous Tools, Pliers, Wrenches, Drills, Mallets, Files, Extension Cords, etc.
 - Power Source

- B) Cut the cable with the hacksaw and then slide the Cap and Fairlead (No. 1), Collar (No. 31), and Main Nut (No. 24) up the cable and push them back out of the way. Liberally lubricate the cable with DC-55 and then slide the various washers and spacers of the upper Housing cavity--Nos. 3 (two), 4 (two), 5, 6, and 8--up the cable in their proper order and push them back out of the way.
- C) End Preparation of the Cable.
1. Study Figure 3-5 carefully to see where the various layers of the cable terminate relative to the Seal components. The stripping length that must be given the most careful attention is that of the inner insulating sheath between the upstream side of the Cerrobend Cup (No. 11) and the upstream side of the Shield Pin (No. 16). The exposed length of this cable layer, after stripping, is 3-3/16 in. Note, however, that lengths may vary slightly from assembly to assembly.
 2. Removing any remaining DC-55 from the area, begin stripping the end of the cable where the seal is to be assembled. The outer Sheath containing the strain wires must be carefully stripped back for a distance somewhat greater than 4-8/16 in. (Note: If the Center Conductor of the cable being used is of sufficient thickness to dispense with the Center Pin (No. 13) as in the Condex and U.S. Steel cables, then cable stripping must begin back an additional 1.62 in. to make up for the Center Pin--see item F.7 of these instructions, below.)
 3. Stripping is accomplished best with a modified soldering unit, equipped at its tip with a hot wire bridge, as shown in Figure 3-6, below. Knives or sharp instruments should be used sparingly, since small nicks in the strain wires diminish the effective strain support, once the strain wires have been potted.

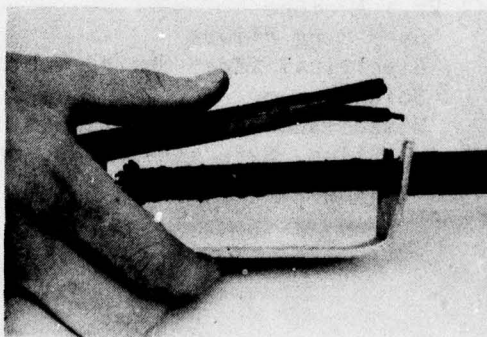


Figure 3-6. Cable Stripping Unit

4. While stripping the polyethylene all around the cable to the level of the strain wires, leave a collar or circular ridge of polyethylene at the very end of the cable to prevent the strain wires from springing out and getting in the way. Once the polyethylene has been stripped to the level of the strain wires, remove the remaining collar and pull the strain wires out with a needle nose pliers. Using the pliers, carefully remove the remaining strips of polyethylene along the inner insulating sheath, taking care not to damage the inner sheath (see Figure 3-7, below).

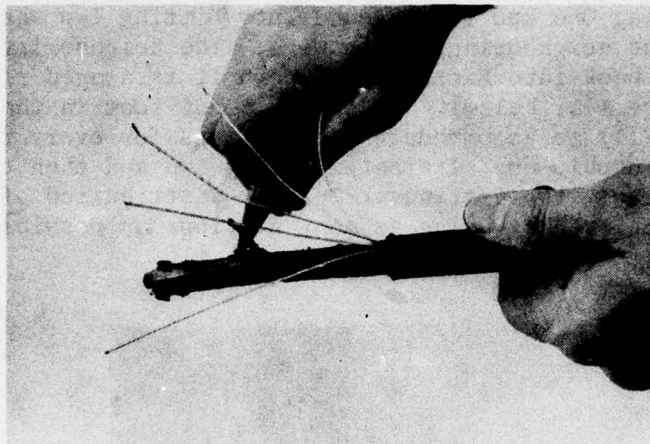


Figure 3-7. Removing Polyethylene Strips
From Inner Sheath

5. Measuring $3\text{--}11/16$ in. (this allows $1/2$ in. for later adjustments) down from the point where the outer sheath terminates, strip the inner polyethylene sheath away from the shield all the way to the end of the cable.
6. Measuring an additional $1\text{--}5/16$ in. from where the inner sheath terminates, remove the shield and core dielectric away from the center conductor.
7. Final termination adjustments for exact lengths of various cable layers should be completed as seals are being assembled along the cable.

D) Coiling and Potting the Cable Strain Wires

1. Glue the two Torque Pin Sleeves (No. 10) into the two socket holes of the Cerrobend Cup (No. 11) with Epoxy glue. Allow to harden.
2. Thread the cable strain wires through the Nicopress Fittings (No. 32) in the following manner, using two fittings for every two strain wires. Slip a fitting up on a strain wire to about 1/16 in. from the outer cable sheath. Slip a second fitting up the neighboring strain wire. Cut the ends of the two strain wires, leaving just enough to loop their ends into and through the neighboring fitting. Thus, a strain wire should pass through Fitting One and loop around into Fitting Two where it is swaged to the neighboring strain wire. The neighboring strain wire should loop back into Fitting One where it is swaged similarly (see Figure 3-8, below). If there is not room in the Cerrobend Cup (No. 11) to accommodate two fittings for every two strain wires, then double up, alternately using two and then three strain wires for every two fittings. Optimum distribution of cable strain is achieved by using as many fittings as possible.

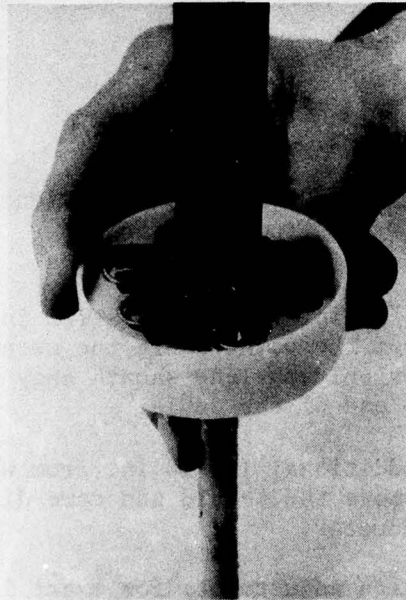


Figure 3-8. Strain Wire and Nicopress Fitting Arrangement

3. Clean off the surface of the Inner Cable Sheath, making sure that nicks, bits of polyethylene and other irregularities are removed. This may be done either by lightly sanding or by heating up the Inner Sheath with the Heat Gun.
4. Set up the Double Boiler, place the Cerrobend Alloy (No. 9) into the beaker, and melt the Alloy using boiling water.
5. Slide the Cerrobend Cup (No. 11) up the cable and then clamp the cable into vertical position with a vise arrangement. Place the Cerrobend Cup Mold around the Cup and tighten it snugly. (Note: The Cup Mold--see Figure 3-9--is constructed from aluminum to fit snugly around the Cup and prevent its expansion during the potting process.) Arrange the Nicopress Fittings in the Cup and then secure the Cup and Cup Mold in a vise, as accurately perpendicular to the cable as possible. This will require careful adjustment and precision. (Note: For a successful potting process, it is necessary that the cable pass perpendicularly through the true center of the cup. If it doesn't, once the cable and strain leads are potted, the steel Tension Washer (No. 8) of the upper assembly will not slide down over the cable into the upper housing. It will then be necessary to melt the Cerrobend back out of the Cup and begin the potting process over.)

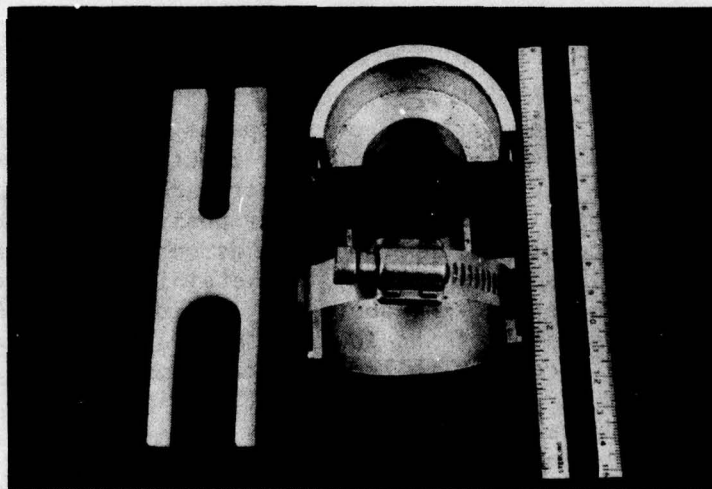


Figure 3-9. Micarta Spacing Fork and Aluminum Cup Mold

6. Pour the Liquid Cerrobend into the Cup, making sure that the Fittings are covered and that the Cup remains perpendicular to the cable. Allow the Cerrobend to cool (see Figure 3-10).

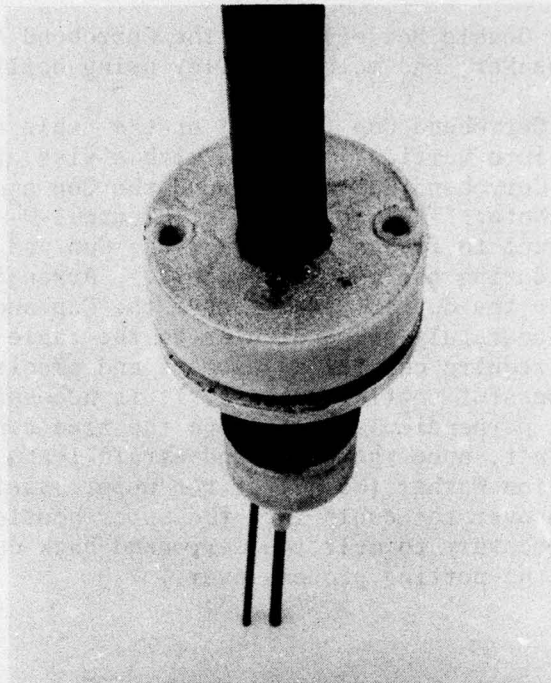


Figure 3-10. Potted Strain Wires

- E) Air Spaces. There are three air spaces in the assembly, two of 1/16-in. and one of 1/4-in. Their function is to accommodate the longitudinal expansion of the rubber packings which must be squeezed radially into their proper positions in the housing bore. The air space of the upper packing assembly above the Cerrobend Cup (No. 11) is guaranteed by the Retaining Ring (No. 7) which fits into its groove 1/16-in. above the Tension Washer (No. 8). However, the two air spaces of the lower assembly beneath the Cup must be temporarily secured with two Micarta Spacing Forks--one of 1/4-in. and another of 1/16-in. thickness (see Figure 3-9). The Spacing Forks are placed in the appropriate positions until the lower seal assembly is ready to be slid into the lower housing bore, at which time the Spacing Forks are removed. The 1/4-in. Spacing Fork is placed just beneath the Torque Washer (No. 12) and the 1/16-in. Spacing Fork fits into position between Washers Nos. 17 and 18, as shown in Figure 3-5. (Note: The exact position of the air spaces is not important, as long as there is one for each cluster of seals between any two fixed or soldered components along the central housing assembly.)

F) Assembling the Lower Seals and Washers

1. Once the Cerrobend has solidified, remove the Cup and cable from their vises and slide the Torque Washer (12) up under the Cup. Place the 1/4-in. Micarta Spacer under the Cup. Lubricate the cable with DC-55 and then slide seals No. 13 (two), the Backup Washer (No. 14) and the Insulator Cup (No. 15) into place.
2. Placing the Shield Pin (No. 16) into position beneath the Insulator Cup (No. 15), determine whether the insulating sheath of the cable has been terminated to its proper length, as shown in Figure 3-5. If not, slide the Shield Pin and Insulator Cup back off and strip the insulating sheath to its proper length.
3. Pre-tin the Shield Pin (No. 16), leaving a solder pool evenly distributed along the lower circumference where the shield strands or tape are to be soldered.
4. Reverse the cable and secure it in place with vises so that it is vertically aligned, with its stripped end uppermost. Slip the Shield Pin in place and secure it there with a vise. Comb the Shield strands out and flatten them in place above the solder pool.
5. Solder the shield strands to the Shield Pin. This should be done as quickly as possible to prevent damage to the polyethylene of the insulators over the central conductor and the shield strands. To diminish the effect of the hot Shield Pin, spray the Freon coolant over the area, immediately after the soldering has been completed. Be sure to restrain the entire arrangement until the cable insulation has cooled down. Trim the shield strands and excess solder with a knife.
6. Slide the two Teflon Washers and the Middle Seals--Nos. 17 (two) and 18 (two)--up over the central cable conductor and Shield Pin, and into place beneath the Shield Pin. Place the Micarta Spacer temporarily between the lower seal and backup washer, to secure the 1/16-in. air space.
7. Solder the Center Pin (No. 23) to the center cable conductor. The shoulder of the Center Pin is an anti-extrusion device, and should be situated at the end where the pin is soldered to the central conductor. Allow the solder joint to cool.
(Note: Cables like the Condex and U.S. Steel types have center conductors of sufficient diameter to dispense with the Center Pin.)

8. Slide the various washers and seals--Nos. 19,20 (two), 21 and 22--over the Center Pin and Shield Pin and into place. The Inner Pressure Washer (No. 19) has a socket on its upstream side to accommodate the shoulder of the Center Pin. Remove the two temporary Micarta spacers of the lower seal assembly.

G) Insertion of the Seal Assembly into the Housing

1. Set up the Vacuum Pump with its bell fitting clamped in a vise, as shown in Figure 3-11.

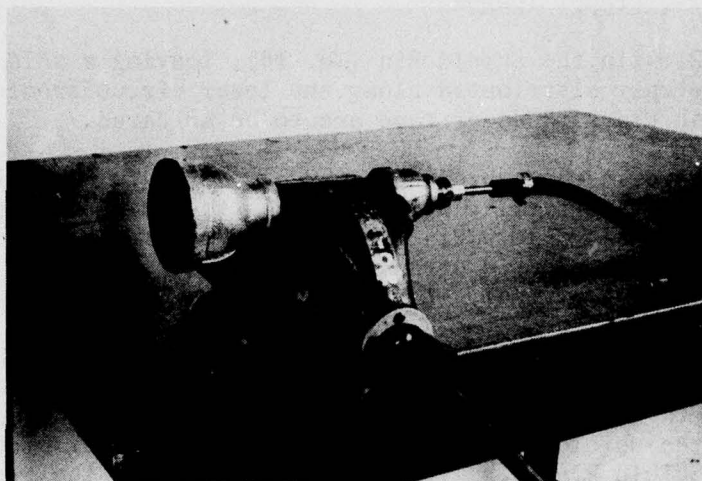


Figure 3-11. Bell Fitting of Vacuum Pump

2. Clean the inner bore of the Cable Seal Housing (No. 2) with acetone and then liberally lubricate it with DC-55, using the foam padded stick to apply lubricant to the lower housing bore. (Note: It is essential that the entire inner bore of the housing be honed. A tool finish is not acceptable due to the extreme friction caused by the length of the assembly, much of which is an interference fit with the housing wall.
3. Slide the lower seal assembly partway down into the lower Housing. Activate the Vacuum Pump and then apply the downstream end of the Housing to the lip of the Bell Fitting. Push on the assembly as the seals are pulled down into the Housing to prevent the seals from being pulled off the Center Pin and Shield Pin. Align the pins of the Torque Washer (No. 12) with their sockets in the Housing wall by pressing and turning until they are properly seated.

4. Making sure that both cable and Housing bore are well lubricated, slide the Spacer (No. 3) and the Tension Washer (No. 8) into place just above the Cerrobend Cup (No. 11) in the upper housing cavity. (Note: At this point, if the cable has not been properly centered in the Cerrobend potting process, the steel Tension Washer will be forced off center by the eccentric cable and will not slide down into the upper housing.)
5. Insert the Retaining Ring (No. 7) into the housing wall, and then slide seals and washers into place--Nos. 6, 5, and 4 (two). In order to get this upper series of seals to seat properly, it is necessary to relieve the air from beneath each seal as it is pushed down into place. This may be done with a small piece of plastic-coated hookup wire, cut carefully so that its inner conducting wires don't protrude. Place the wire along the housing wall and then push each seal into place. The air will bleed back out along the wire. Once the seals are in place, pull the wire out.
6. The optional Delrin Spacer (No. 3) is used only when there is room left over in the housing cavity to fully accommodate it, once all the seals and washers have been installed. It is important not to attempt to apply end pressure to squeeze this spacer into place. If the Spacer protrudes over the edge of the housing when installed, slide it back up and cut it off with a shears.
7. Slide the Main Nut (No. 24) and Collar (No. 31) into place over the outer surface of the Cable Seal Housing. Then screw the Cap and Fairlead (No. 1) into place, tightening them with a strap wrench.

H) Termination with the Repeater Housing Assembly

1. After the Cable Seal has been assembled, the Center Pin and Shield Pin are soldered to their counterparts in the Repeater Assembly which is housed in the Electronics Housing (No. 29). This termination is sealed by using Shrink Tubing. If no electronics are required, the Electronics Housing is replaced with a short transition piece, the Junction Housing (No. 33), which couples the two seal assemblies to one another.

3.5 Design Specifications—Materials and Dimensions

The specifications in this section are for the three types of cable listed before in Section 3.2, namely, the Autec, Condex and U.S. Steel cables. All dimensions are in inches, unless otherwise specified. For each component here described those dimensions that vary according to the cable used are specified in a small table which accompanies the drawing.

Recommended supply sources are not given for such standard materials as commercial Delrin or commercial brass.

Caution: The materials specified in this section have been selected to meet diverse criteria. Substitutions of materials are likely to diminish or destroy the effectiveness of the Seal Assembly.

3.5.1 CAP AND FAIRLEAD: Part No. 1-(X).

A) Materials.

- Fairlead (1) : PRC Moca-Free Potting and Molding Compound, PR1588, Amber or Black.
- : (Alternate Material) PRC Polyurethane Non-Moca-Free Potting and Molding Compound PR1547, Amber or Black.
- : Use Primer PRC No. PR420 with both of the above compounds.
- : Suggested source of supply: Products Research and Chemical Corporation, 2919 Empire Avenue, Burbank, California 91504.

Cap (2) : Carbon Steel AISI 1010-1020; Cadmium Plate.

B) Dimensions (in.). See Figure 3-12, below.

Cable variations, Dimension H:

Dash No.	Dimension H. \pm 0.005 Dia.	Cable
-1	0.370	Autec
-2	0.570	Condex
-3	0.656	U.S. Steel

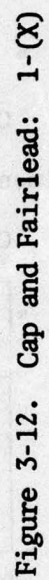
Dimension H is constant through both Cap and Fairlead.

C) Unless otherwise specified.

Tolerances on: Fractions \pm 1/32
Angles \pm 2°

Remove all burrs, break sharp edges: 0.015 Max.

Dimensions and surface roughness to be met after protective coating.



3.5.2 CABLE SEAL HOUSING: Part No. 2.

- A) Materials. Commercial Mild Steel; Cadmium Plate
- B) Special Instructions. Hone all surfaces marked 32✓ after plating.
- C) Dimensions (in.). See Figure 3-13, below.
- D) Unless otherwise specified.

Tolerances on: Fractions $\pm 1/32$
0.XXX ± 0.010
Angles $\pm 2^\circ$

Surface finish: 125✓

Remove all burrs, break sharp edges: 0.015 Max.,
0.005 Min.

Dimensions and surface roughness to be met after
protective coating.

3.5.3 SPACER: Part No. 3-(X).

A) Materials. Commercial Delrin.

B) Dimensions (in.). See Figure 3-14, below.

Cable variations, Dimension H:

Dash No.	Dimension H \pm 0.005 Dia.	Cable
-1	0.781	Autec
-2	0.890	Condex
-3	1.000	U.S. Steel

C) Unless otherwise specified.

Tolerances on: 0.XXX \pm 0.010

Surface finish: 125✓

Remove all burrs, break sharp edges: 0.015 Max.

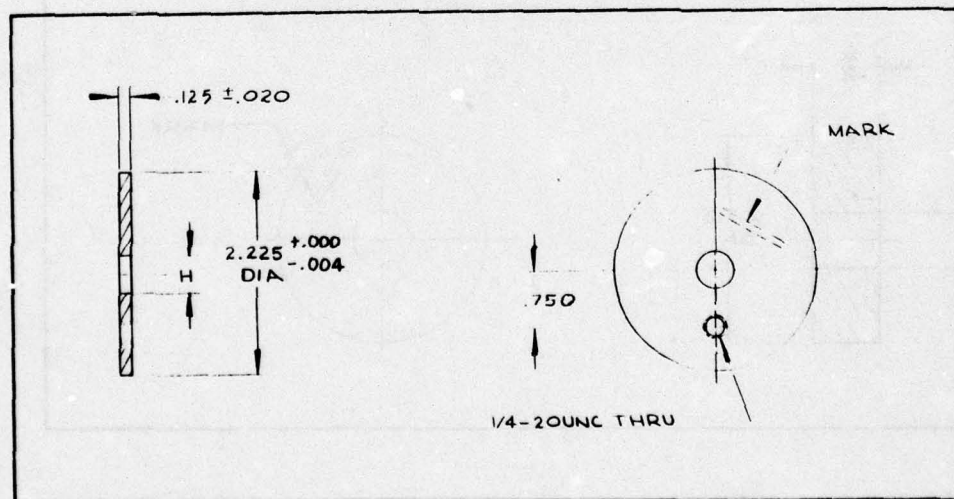


Figure 3-14. Spacer: 3-(X)

AD-A036 841

WASHINGTON UNIV SEATTLE APPLIED PHYSICS LAB
INTERFERENCE SEALS AND CONNECTORS FOR UNDERSEA
JUL 76 J PARADIS

F/G 13/10
ELECTRICAL APPLI--ETC(U)
N00017-74-C-1208
NL

UNCLASSIFIED

2 OF 4
AD
A036 841



3.5.4 SEAL WASHER: Part No. 4-(X).

A) Materials. Commercial Neoprene, 35 ± 5 Durometer.

B) Dimensions (in.). See Figure 3-15, below.

Cable variations, Dimension H:

Dash No.	Dimension H ± 0.010 Dia.	Cable
-1	0.500	Autec
-2	0.625	Condex
-3	0.750	U.S. Steel

C) Unless otherwise specified.

Tolerances on: $0.XXX \pm 0.010$

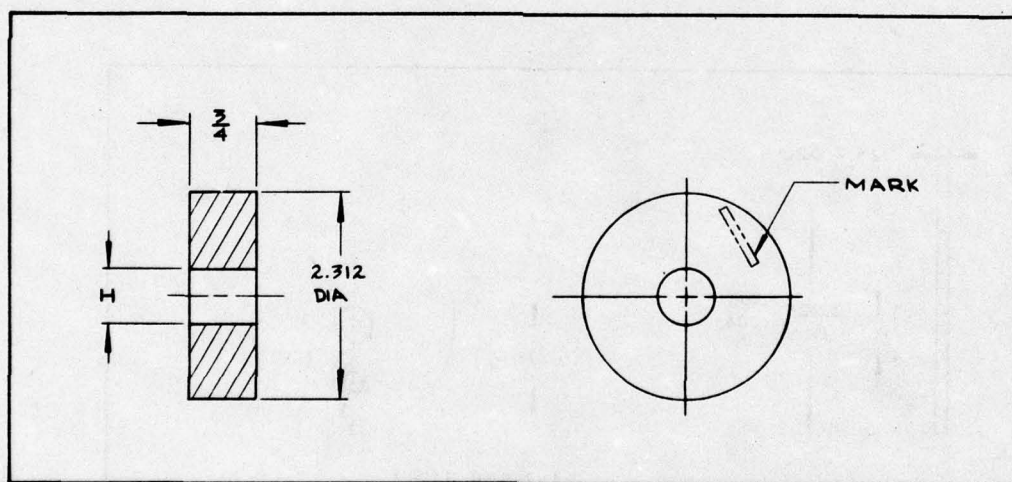


Figure 3-15. Seal Washer: 4-(X)

3.5.5 BACKUP WASHER: Part No. 5-(X).

A) Materials. Commercial Neoprene, 70 ± 5 Durometer.

B) Dimensions (in.). See Figure 3-16, below.

Cable variations, Dimension H:

Dash No.	Dimension H ± 0.010 Dia.	Cable
-1	0.660	Autec
-2	0.780	Condex
-3	0.900	U.S. Steel

C) Unless otherwise specified.

Tolerances on: $0.XXX \pm 0.010$

Surface finish: 125 \sqrt

Remove all burrs, break sharp edges: 0.015 Max.

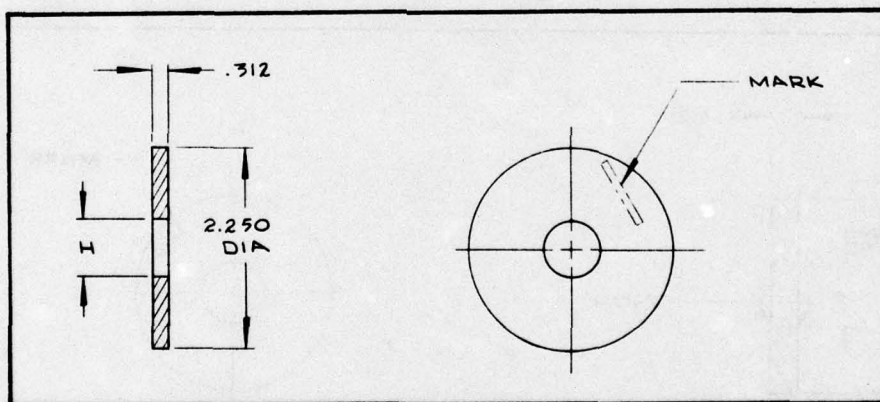


Figure 3-16. Backup Washer: 5-(X)

3.5.6 THRUST WASHER: Part No. 6-(X).

A) Materials. Commercial Mild Steel; Cadmium Plate.

B) Dimensions (in.). See Figure 3-17, below.

Cable variations, Dimension H:

Dash No.	Dimension H \pm 0.005 Dia.	Cable
-1	0.781	Autec
-2	0.890	Condex
-3	1.000	U.S. Steel

C) Unless otherwise specified.

Tolerances on: 0.XXX \pm 0.010

Surface finish: 125 \sqrt

Remove all burrs, break sharp edges: 0.008 Max.

Dimensions and surface roughness to be met after protective coating.

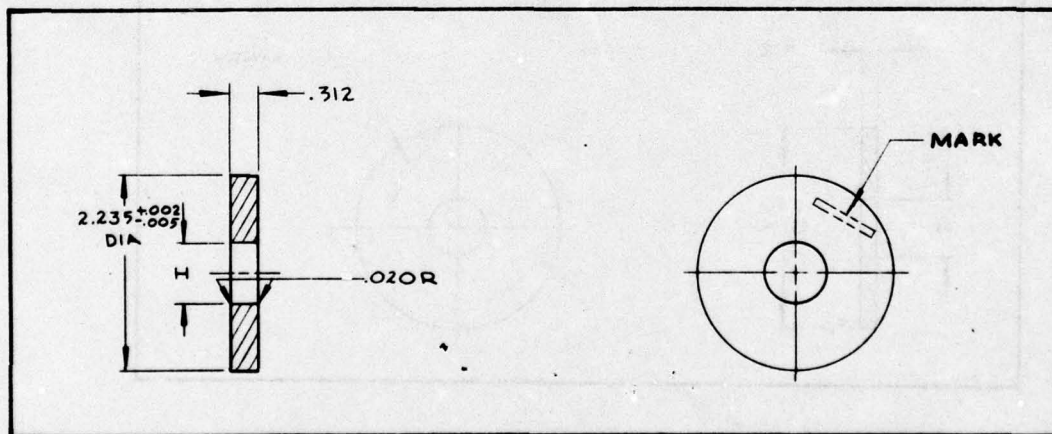


Figure 3-17. Thrust Washer: 6-(X)

3.5.7 TENSION WASHER: Part No. 8-(X).

A) Materials. Commercial Mild Steel; Cadmium Plate.

B) Dimensions (in.). See Figure 3-18, below.

Cable variations, Dimension H:

Dash No.	Dimension H \pm 0.005 Dia.	Cable
-1	0.781	Autec
-2	0.890	Condex
-3	1.000	U.S. Steel

C) Unless otherwise specified.

Tolerances on: 0.XXX \pm 0.010

Surface finish: 125 \sqrt

Remove all burrs, break sharp edges: 0.008 Max.

Dimensions and surface roughness to be met after protective coating.

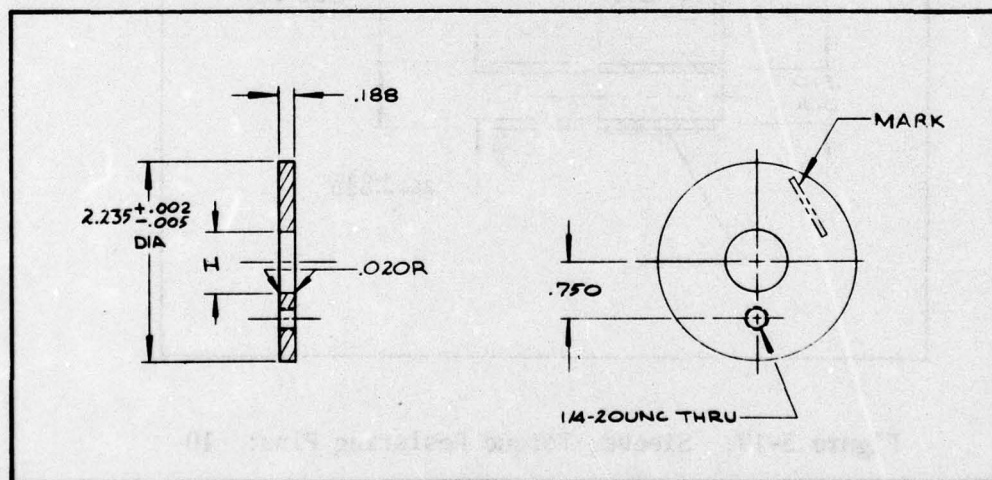


Figure 3-18. Tension Washer: 8-(X)

3.5.8 SLEEVE, TORQUE RESISTING PINS: Part No. 10.

- A) Materials. Commercial Delrin.
- B) Special Instructions. After potting, trim sleeve flush to surface of potting material, if necessary.
- C) Dimensions (in.). See Figure 3-19, below.
- D) Unless otherwise specified.

Tolerances on: $0.XXX \pm 0.010$
Fractions $\pm 1/32$

Surface finish: 125

Machined Fillets: $0.015 R \pm \text{Max.}$

Remove all burrs, break sharp edges: 0.015 Max.

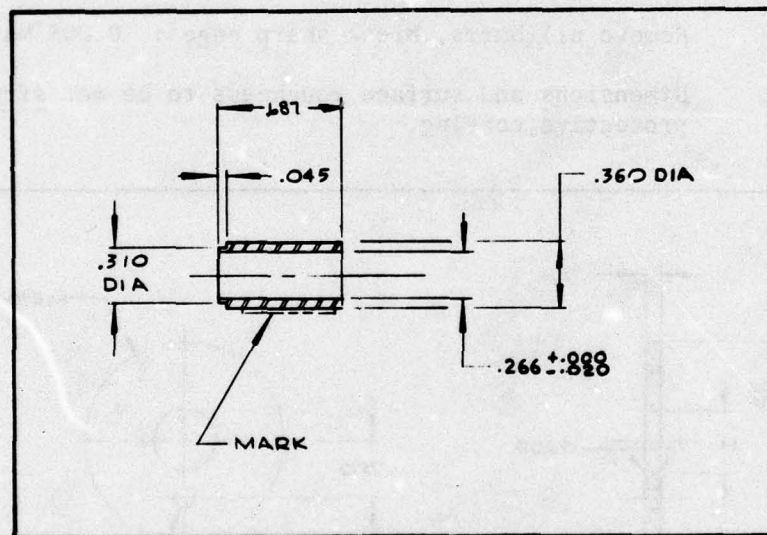


Figure 3-19. Sleeve, Torque Resisting Pins: 10

3.5.9 CUP: Part No. 11-(X).

A) Materials. Commercial Delrin.

B) Dimensions (in.). See Figure 3-20, below.

Cable variations, Dimension H:

Dash No.	Dimension H \pm 0.005 Dia.	Cable
-1	0.370	Autec
-2	0.590	Condex
-3	0.656	U.S. Steel

C) Unless otherwise specified.

Tolerances on: 0.XXX \pm 0.010
Fractions \pm 1/32

Surface finish: 125

Machined Fillets: 0.015 R \pm Max.

Remove all burrs, break sharp edges: 0.015 Max.

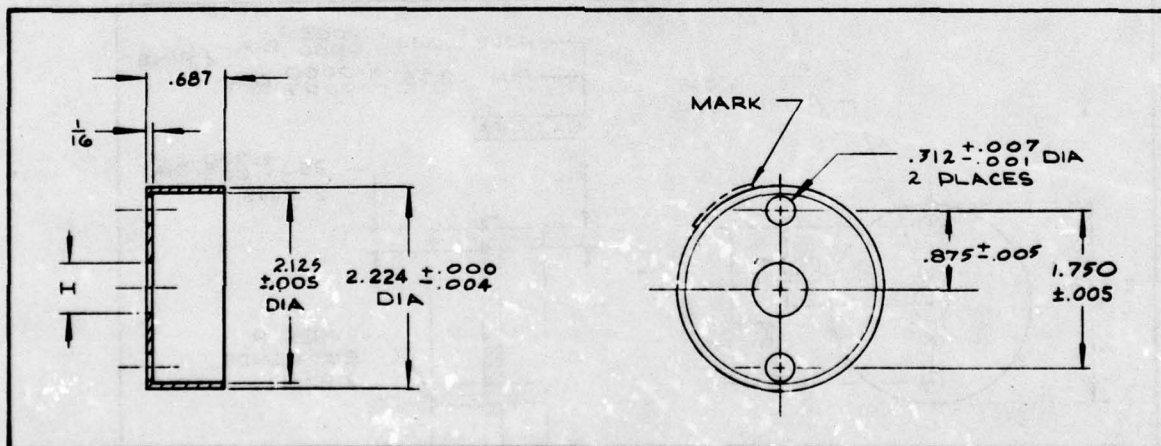


Figure 3-20. Cup: 11-(X)

3.5.10 TORQUE WASHER: Part No. 12-(X).

- A) Materials. Steel AISI 1010-1020; Cadmium Plate per QQ-P-416, Type II, Class 1 (0.0005 Thk.).
- B) Dimensions (in.). See Figure 3-21, below.

Cable variations, Dimension A:

Dash No.	Dimension A	Cable
-1	0.391	Autec
-2	0.609	Condex
-3	0.672	U.S. Steel

- C) Unless otherwise specified.

Tolerances on: $0.XX \pm 0.02$
 $0.XXX \pm 0.010$

Surface finish: 125✓

Remove all burrs, break sharp edges: 0.016 Max.

Dimensions and surface roughness to be met after protective coating.

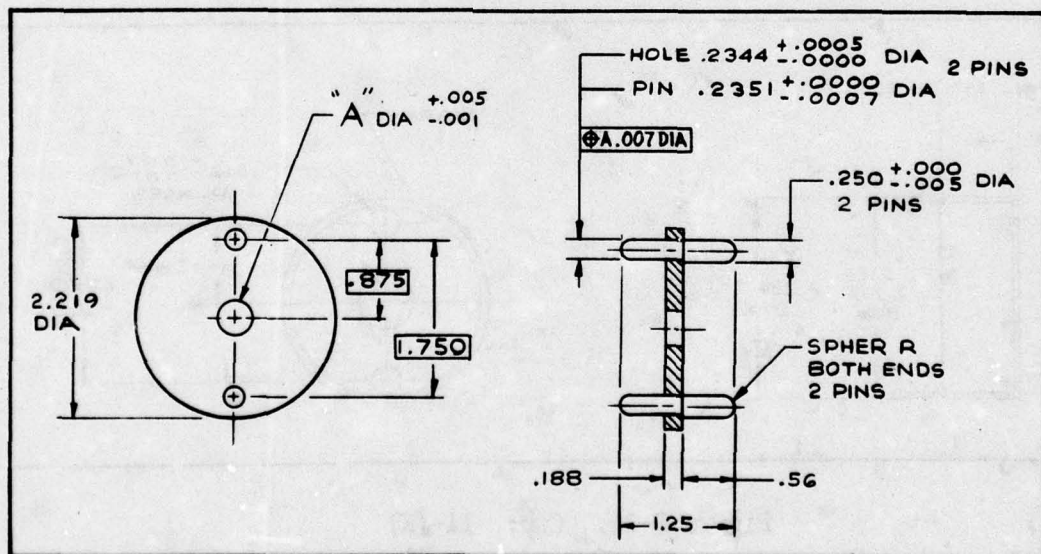


Figure 3-21. Torque Washer: 12-(X)

3.5.11 INNER JACKET SEAL: Part No. 13-(X).

A) Materials. Commercial Neoprene, 35 ± 5 Durometer.

B) Dimensions (in.). See Figure 3-22, below.

Cable variations, Dimension H:

Dash No.	Dimension H ± 0.005 Dia.	Cable
	0.340	Autec
-2 or -3	0.515	Condex U.S. Steel

C) Unless otherwise specified.

Tolerances on: $0.XXX \pm 0.010$
Fractions $\pm 1/32$

Surface finish: 125 ✓

Remove all burrs, break sharp edges: 0.015 Max.

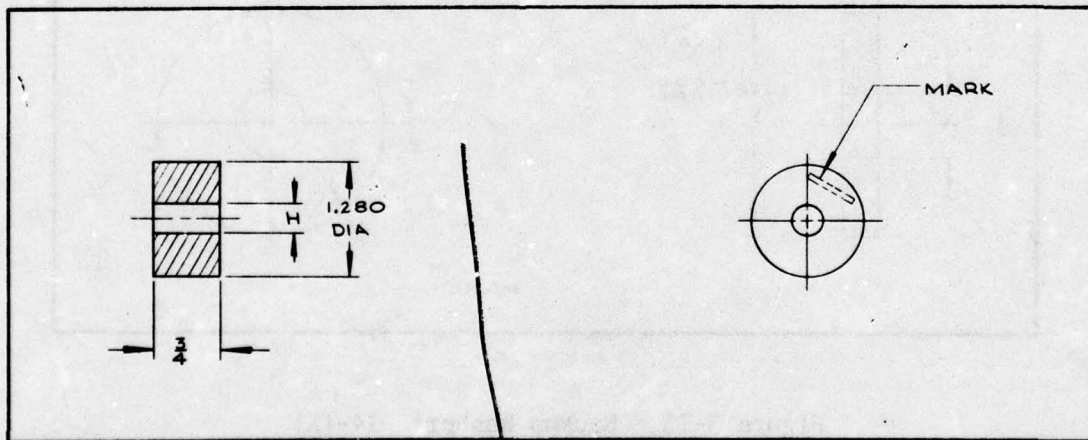


Figure 3-22. Inner Jacket Seal: 13-(X)

3.5.12 BACKUP WASHER: Part No. 14-(X).

A) Materials. Commercial Teflon.

B) Dimensions (in.). See Figure 3-23, below.

Cable variations, Dimension H:

Dash No.	Dimension H \pm 0.005 Dia.	Cable
-1	0.370	Autec
-2	0.570	Condex
-3	0.656	U.S. Steel

C) Unless otherwise specified.

Tolerances on: 0.XXX \pm 0.010

Surface finish: 125

Remove all burrs, break sharp edges: 0.015 Max.

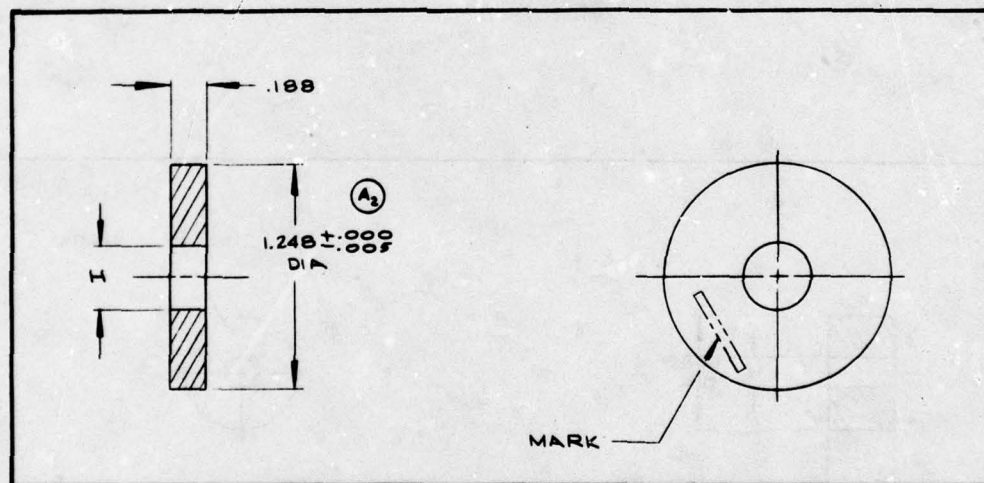


Figure 3-23. Backup Washer: 14-(X)

3.5.13 INSULATOR CUP: Part No. 15-(X).

A) Materials. Commercial Delrin.

B) Dimensions (in.). See Figure 3-24, below.

Cable variations, Dimension H:

Dash No.	Dimension H \pm 0.005 Dia.	Cable
-1	0.375	Autec
-2	0.578	Condex
-3	0.656	U.S. Steel

C) Unless otherwise specified.

Tolerances on: 0.XXX \pm 0.010
Fractions \pm 1/32

Surface finish: 125 \sqrt

Machined Fillets: 0.015 R \pm Max.

Remove all burrs, break sharp edges: 0.015 Max.

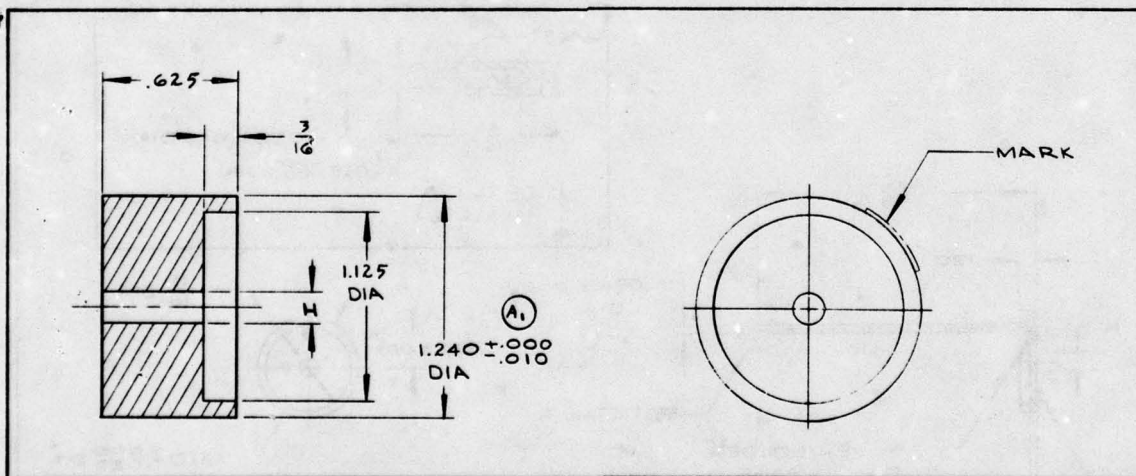


Figure 3-24. Insulator Cup: 15-(X)

3.5.14 SHIELD PIN: Part No. 16-(X).

A) Materials. Commercial Brass.

B) Dimensions (in.). See Figure 3-25, below.

Cable variations, Dimension H:

Dash No.	Dimension H \pm 0.005 Dia.	Cable
-1	0.261	Autec
-2	0.500	Condex
-3	0.562	U.S. Steel

C) Unless otherwise specified.

Tolerances on: 0.XXX \pm 0.010
Angles \pm 2°
Fractions \pm 1/32

Surface finish: 125 \sqrt

Machined Fillets: 0.015 R \pm Max.

Remove all burrs, break sharp edges: 0.015 Max.

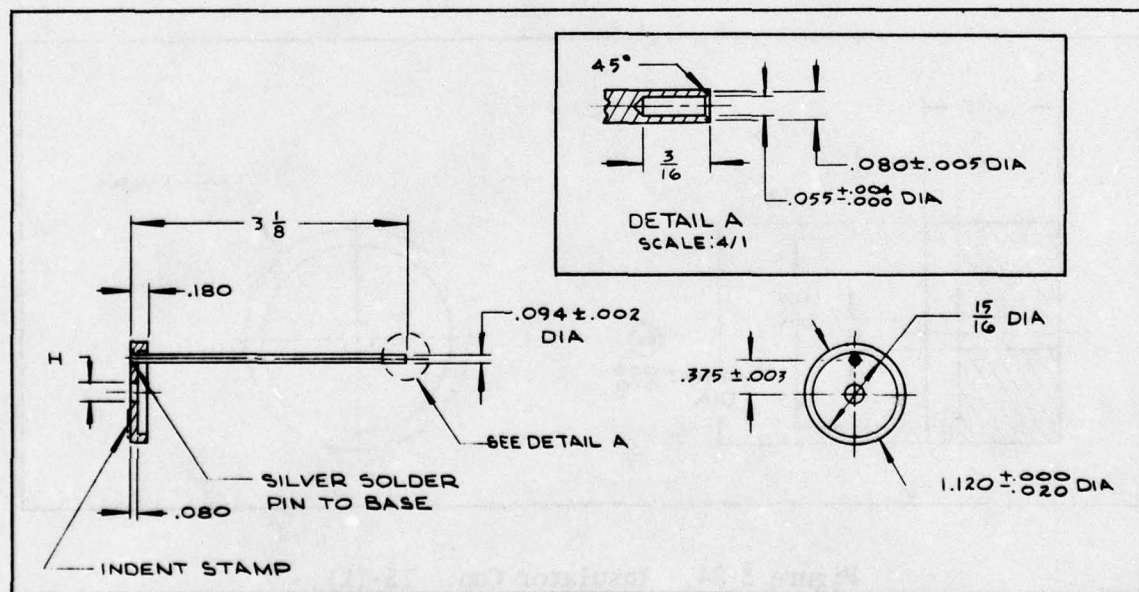


Figure 3-25. Shield Pin: 16-(X)

3.5.15 MIDDLE BACKUP WASHER: Part No. 17-(X).

A) Materials. Commercial Teflon.

B) Dimensions (in.). See Figure 3-26, below.

Cable variations, Dimension H:

Dash No.	Dimension $H \pm 0.005$ Dia.	Cable
-1	0.185	Autec
-2	0.422	Condex
-3	0.469	U.S. Steel

C) Unless otherwise specified.

Tolerances on: $0.XXX \pm 0.010$

Surface finish: 125 \sqrt

Remove all burrs, break sharp edges: 0.015 Max.

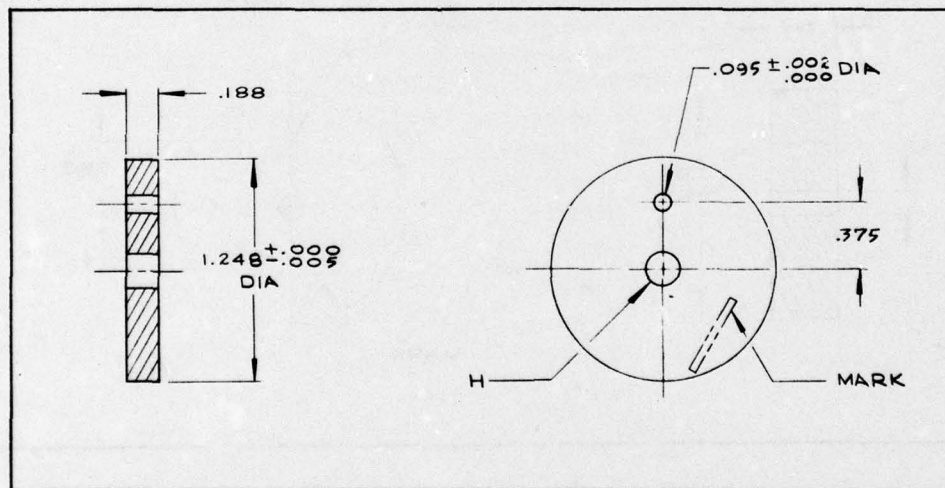


Figure 3-26. Middle Backup Washer: 17-(X)

3.5.16 MIDDLE SEAL: Part No. 18-(X).

A) Materials: Chlorinated Butyl, 35 ± 5 Durometer.

B) Dimensions (in.). See Figure 3-27, below.

Cable variations, Dimension H:

Dash No.	Dimension $H \pm 0.005$ Dia.	Cable
-1	0.130	Autec
-2	0.370	Condex
-3	0.413	U.S. Steel

C) Unless otherwise specified.

Tolerances on: $0.XXX \pm 0.010$

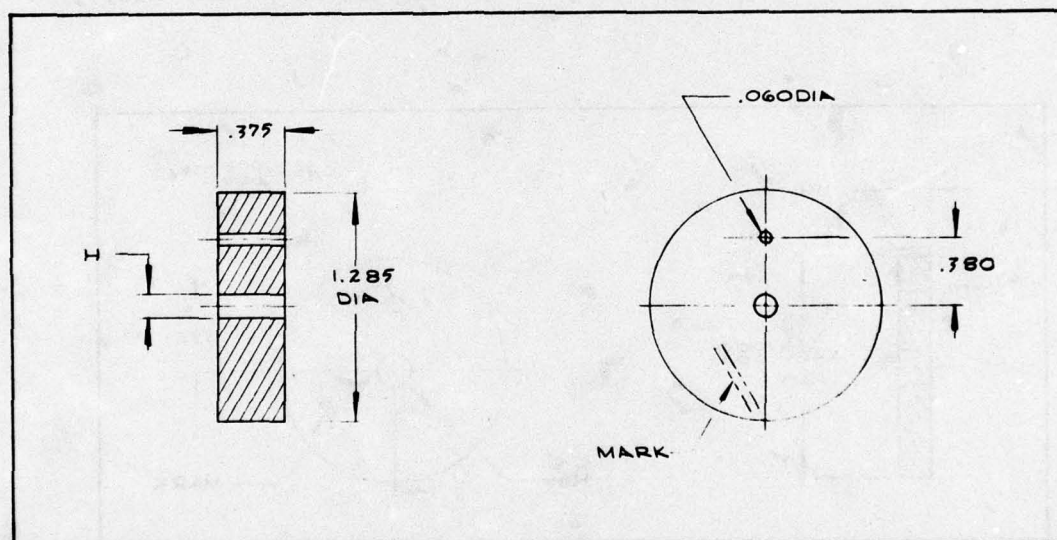


Figure 3-27. Middle Seal: 18-(X)

3.5.17 INNER PRESSURE WASHER: Part No. 19.

- A) Materials. Commercial Teflon.
- B) Dimensions (in.). See Figure 3-28, below.
- C) Unless otherwise specified.

Surface finish: 125/

Remove all burrs, break sharp edges: 0.015 Max.

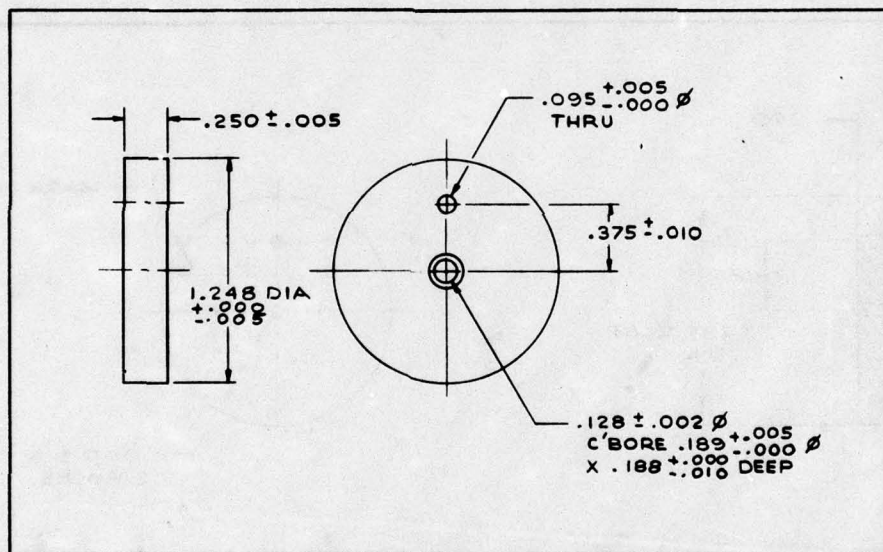


Figure 3-28. Inner Pressure Washer: 19

3.5.18 INNER SEAL: Part No. 20

- A) Materials. Chlorinated Butyl, 35 ± 5 Durometer.
- B) Dimensions (in.). See Figure 3-29, below.
- C) Unless otherwise specified.

Tolerances on: $0.XXX \pm 0.010$

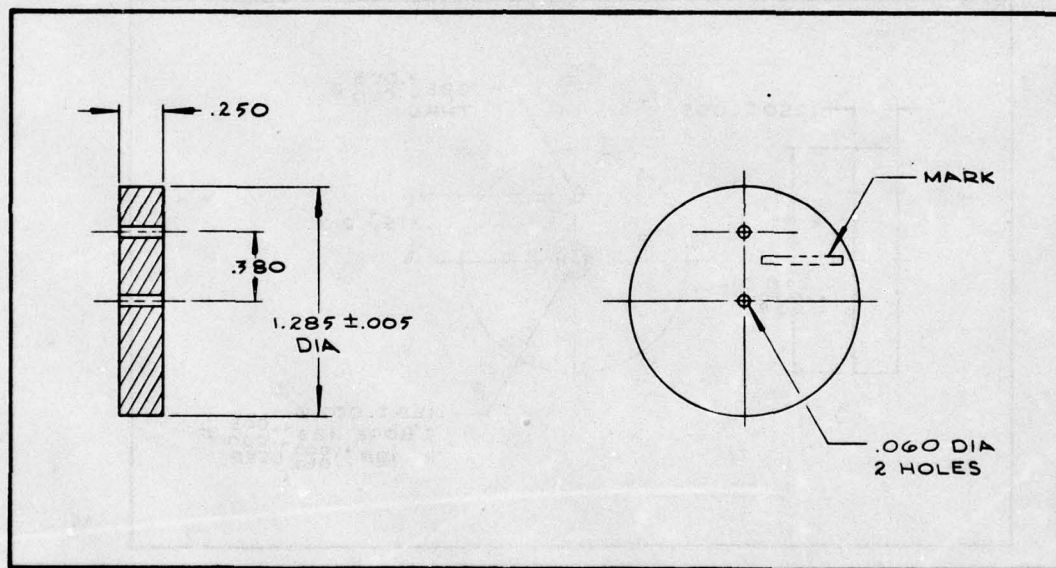


Figure 3-29. Inner Seal: 20

3.5.19 LOWER PRESSURE WASHER: Part No. 21-(1).

- A) Materials. Commercial Teflon.
- B) Dimensions (in.). See Figure 3-30, below.

Cable variations, Dimension T:

Dash No.	Dimension $T \pm 0.005$ Dia.	Cable
-1	0.188	Autec
-2	0.250	Condex
-3	0.125	U.S. Steel

- C) Unless otherwise specified.

Tolerances on: $0.XXX \pm 0.010$

Surface finish: 125 \sqrt

Remove all burrs, break sharp edges: 0.015 Max.

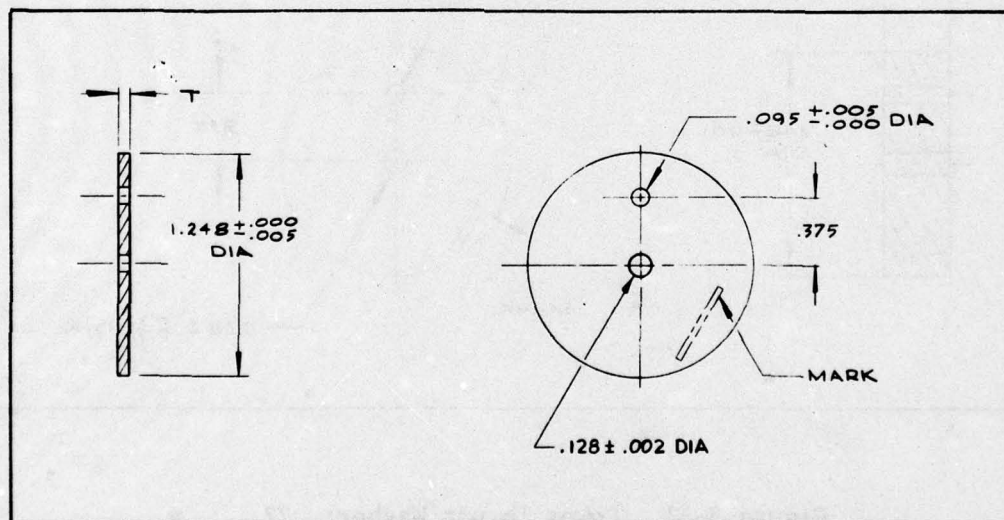


Figure 3-30. Lower Pressure Washer: 21-(1)

3.5.20 LOWER THRUST WASHER: Part No. 22

- A) Materials. Epoxy Glass Nema G10
- B) Dimensions (in.). See Figure 3-31, below.
- C) Unless otherwise specified.

Tolerances on: $0.XXX \pm 0.010$

Surface finish: 125

Remove all burrs, break sharp edges: 0.015 Max.

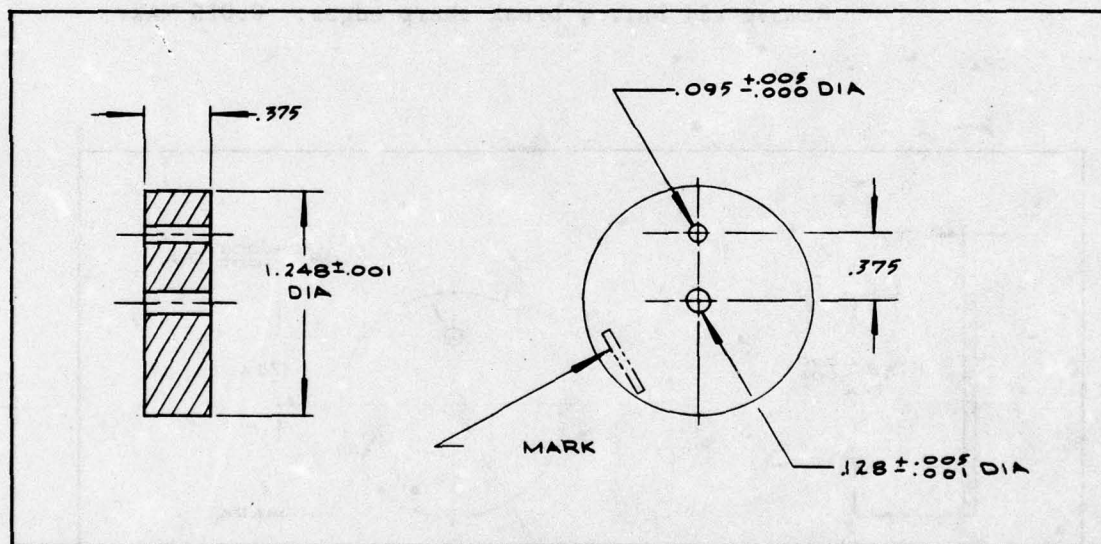


Figure 3-31. Lower Thrust Washer: 22

3.5.21 CENTER PIN: Part No. 23.

- A) Materials. Commercial Brass, Nickel Plate per QQ-N-290, Class 2, Type V ($0.0005 + 0.0002$ Thk)
- 0.0000 Thk)
- B) Special Instructions: Omit center pin on -2 (Condex) and -3 U.S.S. assemblies.
- C) Dimensions (in.). See Figure 3-32, below.
- D) Unless otherwise specified.

Tolerances on: $0.XX \pm 0.03$
 $0.XXX \pm 0.010$

Surface finish: 125✓

Remove all burrs, break sharp edges: 0.015 Max.

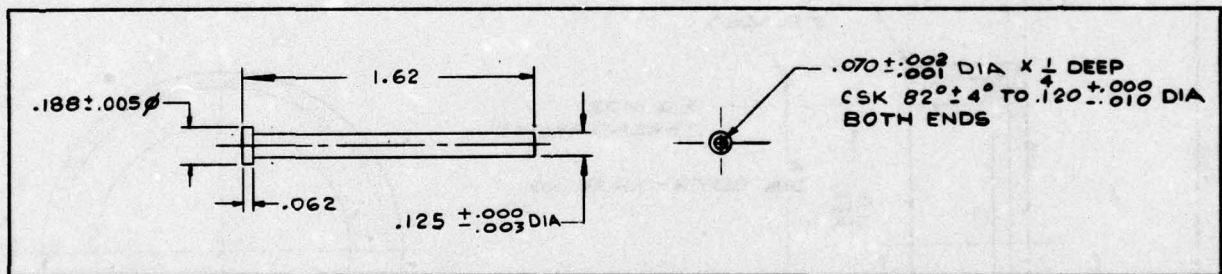


Figure 3-32. Center Pin: 23

3.5.22 MAIN NUT: Part No. 24.

- A) Materials. Commercial Mild Steel; Cadmium Plate.
- B) Dimensions (in.). See Figure 3-33, below.
- C) Unless otherwise specified.

Tolerances on: $0.XXX \pm 0.010$
Fractions $\pm 1/32$

Surface finish: 125/

Remove all burrs, break sharp edges: 0.015 Max.

Dimensions and surface roughness to be met after protective coating.

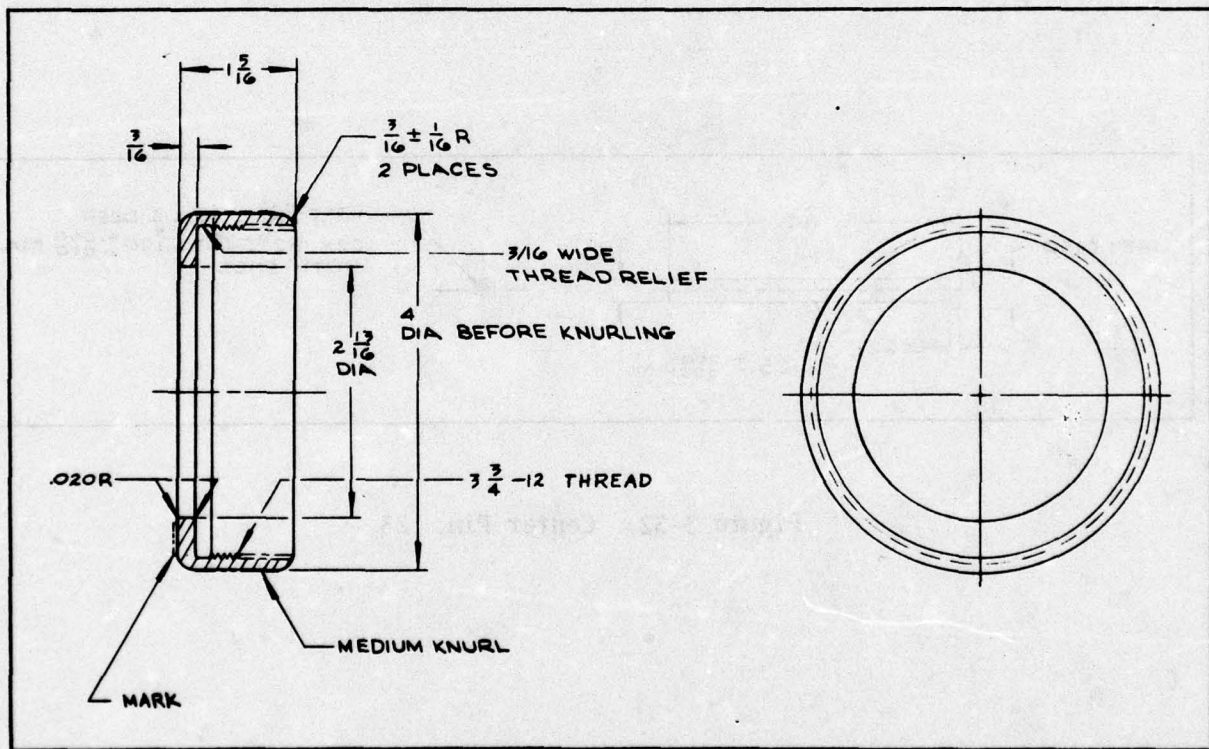


Figure 3-33. Main Nut: 24

3.5.23 SPACER: Part No. 27.

- A) Materials. Commercial Nylon or Delrin.
- B) Dimensions (in.). See Figure 3-34, below.
- C) Unless otherwise specified.

Tolerances on: $0.XXX \pm 0.010$
Fractions $\pm 1/32$

Surface finish: 125/

Machined Fillets: $0.031 R \pm \text{Max.}$

Remove all burrs, break sharp edges: 0.031 Max.

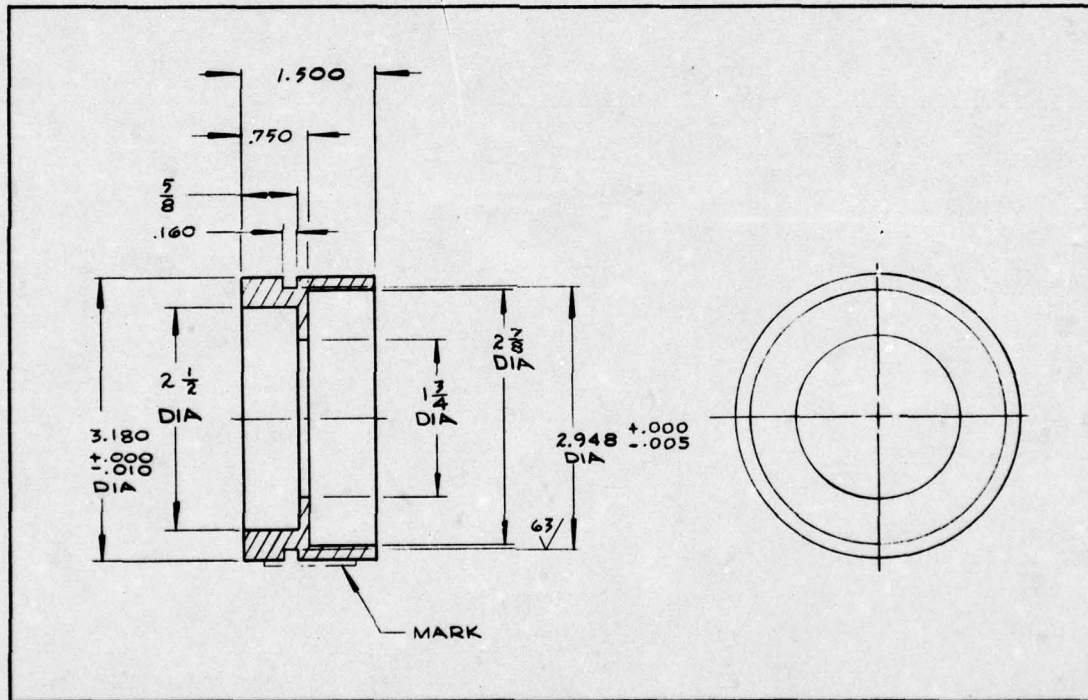


Figure 3-34. Spacer: 27

3.5.24 ELECTRONICS HOUSING: Part No. 29.

- A) Materials. Commercial Mild Steel; Cadmium Plate.
- B) Dimensions (in.). See Figure 3-35, below.
- C) Unless otherwise specified.

Tolerances on: $0.XXX \pm 0.010$
Angles $\pm 2^\circ$
Fractions $\pm 1/32$

Surface finish: 125/

Remove all burrs, break sharp edges: 0.015 Max.,
0.005 Min.

Dimensions and surface roughness to be met after
protective coating.

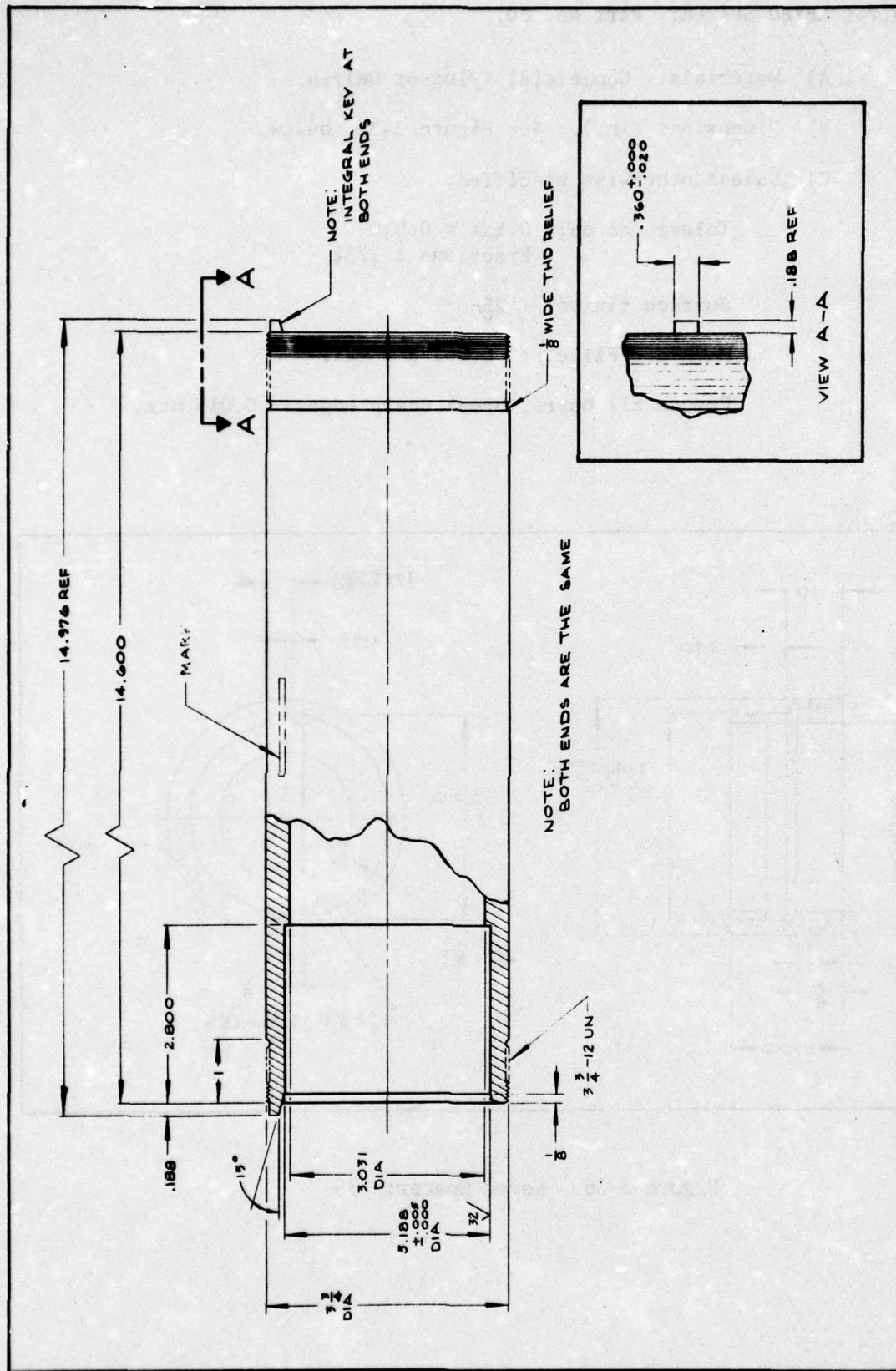


Figure 3-35. Electronics Housing: 29

3.5.25 KEYED SPACER: Part No. 30.

- A) Materials. Commercial Nylon or Delrin.
- B) Dimensions (in.). See Figure 3-36, below.
- C) Unless otherwise specified.

Tolerances on: $0.XXX \pm 0.010$
Fractions $\pm 1/32$

Surface finish: 125

Machined Fillets: $0.031 R \pm \text{Max.}$

Remove all burrs, break sharp edges: 0.015 Max.

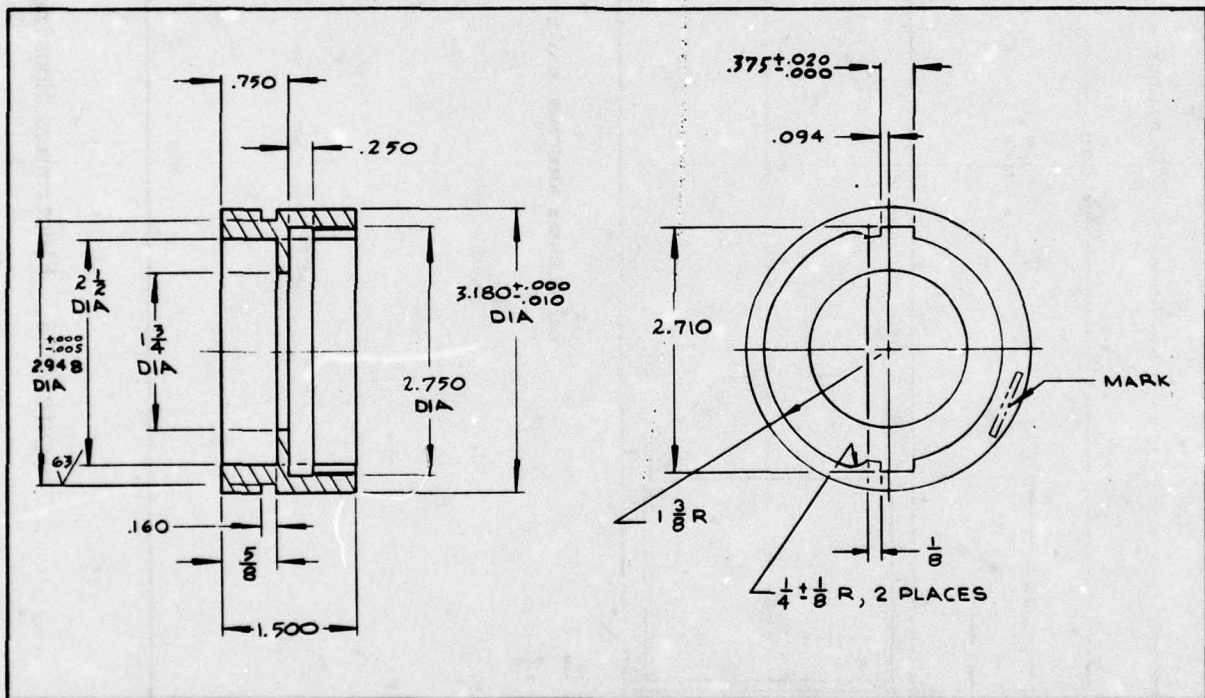


Figure 3-36. Keyed Spacer: 30

3.5.26 COLLAR: Part No. 31.

- A) Materials. Commercial Delrin.
- B) Dimensions (in.). See Figure 3-37, below.
- C) Unless otherwise specified.

Tolerances on: Fractions $\pm 1/32$

Surface finish: 125 \sqrt

Remove all burrs, break sharp edges: 0.031 Max.

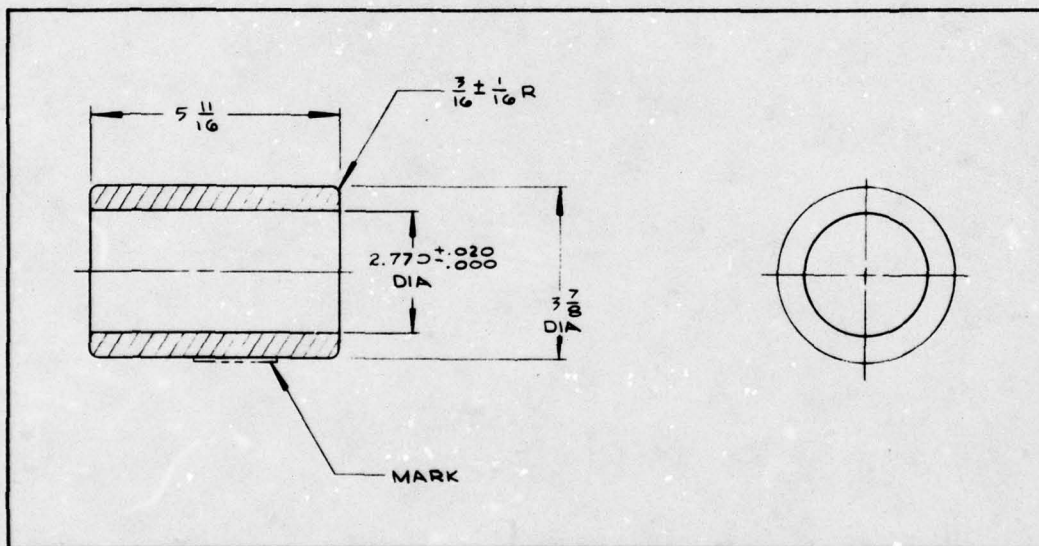


Figure 3-37. Collar: 31

3.5.27 JUNCTION HOUSING (OPTIONAL): Part No. 33.

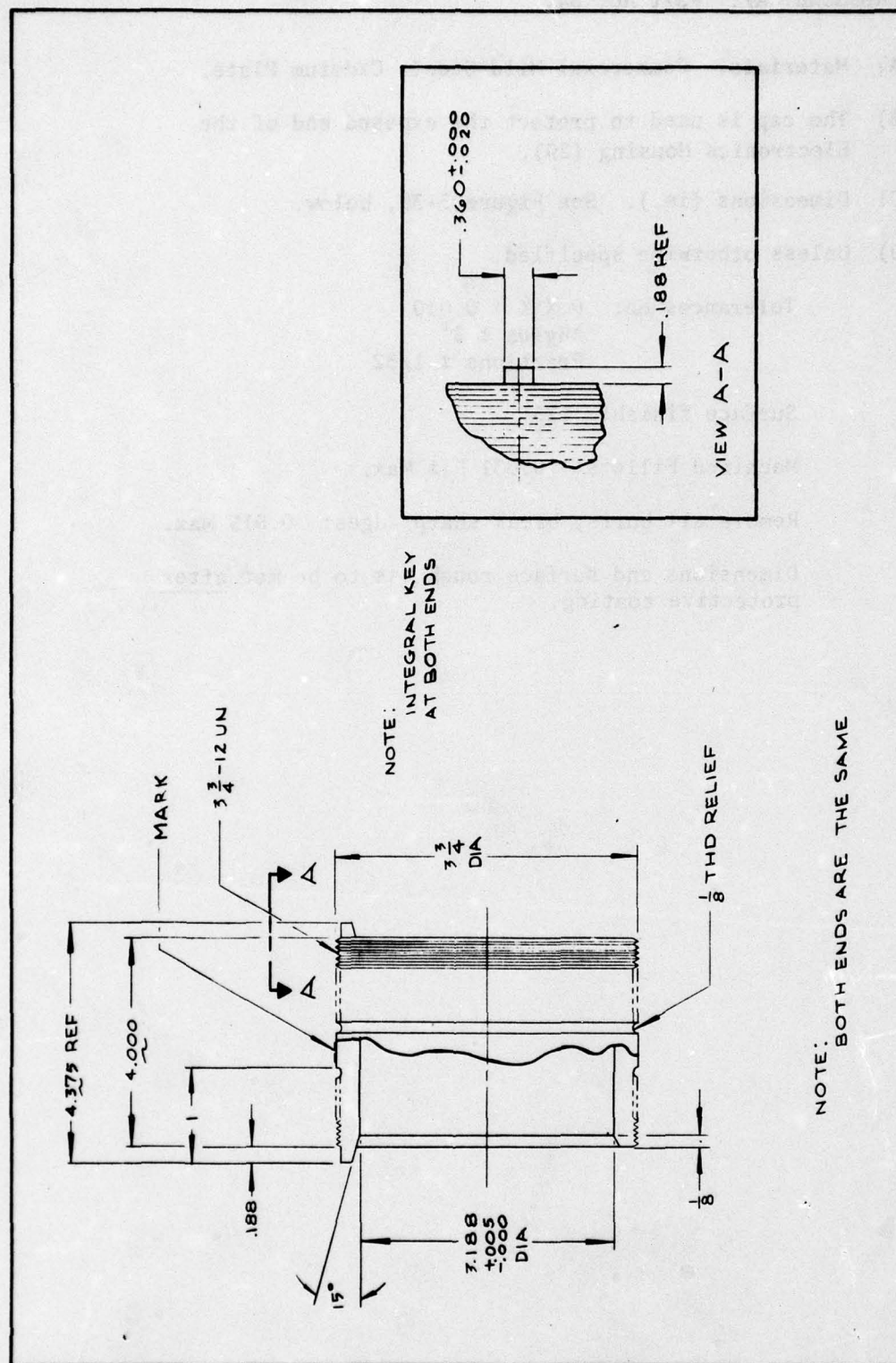
- A) Materials. Commercial Mild Steel.
- B) The Junction Housing is used to connect two Cable Seal Assemblies without using Items 27, 28, 29 and 30.
- C) Dimensions (in.). See Figure 3-38, below.
- D) Unless otherwise specified.

Tolerances on: $0.XXX \pm 0.010$
Angles $\pm 2^\circ$
Fractions $\pm 1/32$

Surface finish: 125 \sqrt

Remove all burrs, break sharp edges: 0.015 Max.,
0.005 Min.

Dimensions and surface roughness to be met after
protective coating.



3.5.28 PRESSURE CAP: Part No. 34.

- A) Materials. Commercial Mild Steel; Cadmium Plate.
- B) The cap is used to protect the exposed end of the Electronics Housing (29).
- C) Dimensions (in.). See Figure 3-39, below.
- D) Unless otherwise specified.

Tolerances on: $0.XXX \pm 0.010$
Angles $\pm 2^\circ$
Fractions $\pm 1/32$

Surface finish: 125 \sqrt

Machined Fillets: $0.031 R \pm \text{Max.}$

Remove all burrs, break sharp edges: 0.015 Max.

Dimensions and surface roughness to be met after protective coating.



Figure 3-39. Pressure Cap: 34

Section 4

TABLE OF CONTENTS

<u>Section</u>	<u>Title</u>	<u>Page</u>
4.1	Introduction	4-1
4.1.1	Scope	4-3
4.2	Critical Design Factors	4-4
4.2.1	The Housing	4-6
4.2.2	Electrical Contacts	4-7
4.2.3	Electrical Insulation	4-8
4.2.4	Cable to Plug/Receptacle Seals and Mating Seals	4-8
4.2.5	Strength Member Termination and Strain Relief	4-9
4.3	Connector Classification	4-10
4.3.1	Molded Rubber Assemblies (RM)	4-10
4.3.2	Molded Plastic Assemblies (PM)	4-11
4.3.3	Metal Shell Assemblies (MS)	4-12
4.3.4	Pressure-balanced Oil-filled Assemblies (PBOF)	4-14
4.3.5	Underwater Mateable Assemblies (UM)	4-14
4.4	Connector Matrices	4-15
4.4.1	Matrix Disclaimer	4-15
4.5	References	4-16

Section 4

LIST OF FIGURES AND TABLES

<u>Figure</u>	<u>Title</u>	<u>Page</u>
4-1	Underwater Electrical Connector Design Considerations	4-5

<u>Table</u>	<u>Title</u>	<u>Page</u>
4-1	Connector Classes	4-10

Section 4

COMMERCIAL OFF-THE-SHELF UNDERWATER ELECTRICAL CONNECTORS- A CLASSIFICATION WITH DESCRIPTIVE MATRICES

4.1 Introduction

Approximately twenty companies are manufacturing commercial lines of off-the-shelf underwater electrical connectors today. In addition, these same companies, together with another ten or so special design organizations, do a substantial business in supplying underwater connectors to meet special requirements specified by various industrial and military customers. The underwater cable termination business is a multimillion dollar industry which is undergoing substantial development and moving toward an increasingly sophisticated and reliable technology.

It remains a fact, however, that few underwater connector series have been in use for more than 10 years and that design standards vary from organization to organization, with the exception of manufacturers utilizing Military Specifications. And even Military Specifications, as a 1969 report (Reference 2) has demonstrated, are patchy and frequently inadequate for more demanding deep ocean applications: "Electrical distribution systems have always been one of the critical subsystems in deep submergence operations. Problems arise not only from material and test specifications, but even from a supporting theory necessary for accurate use of test data and procedures." The deficiency in a general design theory for underwater electrical connectors has been partially corrected by a 1971 study (Reference 1).

Development of high-reliability connectors may require contractual documentation of the batch materials used in each device in order to establish performance history. Component traceability and labeling need to be accepted industry procedures. Formal test documentation, including failure, materials and design analyses, should be specified whenever other than production contracts are involved. Not only is

such documentation needed for expeditious hardware development, but it is also necessary for vendor qualification, and vehicle or system certification.

The capabilities of manufacturers are growing, however. Increasing research and development and expanded quality-control procedures have brought manufacturers a growing and respectable clientele over the past five years, and there are significant advantages to be obtained in using a number of the off-the-shelf connectors now available.

The chief advantages the connector manufacturer offers the prospective buyer are in terms of time and cost. A wide variety of moderately priced commercial terminations is now available, and many manufacturers can begin delivery of terminated cable systems within 5-8 weeks. Additional advantages are to be had in the numerous design options now available, in the accruing special design experience of most manufacturers, and in the factory facilities that will often allow for such quality-control testing procedures as are specified by the buyer.

A number of new developments have also occurred in connector technology. The connector seminar at the 1976 Offshore Technology Conference aired, although not decisively, the bond vs boot and the factory vs field capability question. Generally, factory terminations and bonded seals offer increased reliability. However, field termination, utilizing booted cable to connector seals, offers such advantages in terms of flexibility that a well-designed field-installable connector is frequently to be preferred. A third basic option, as pointed out in a recent study (see Reference 3), is that of wet vs dry connector capability. Among other things, underwater mateability allows cable structures to be aligned better, with less slack; also the order of events can be altered significantly if connections can be made underwater.

Most connector manufacturers exhibiting at the 1976 Offshore Technology Conference displayed new hardware which included upgraded standard designs and a variety of new connectors. Underwater mateability, once a rare capability--with the exception of the standard

sliding rubber seal design of Electro Oceanics, Inc.--has become more available with a new generation of connectors developed at the Naval Civil Engineering Laboratory (NCEL) at Port Hueneme, California, and a range of new underwater mateables developed by Viking, Rochester/Brantner, and Glenaire, Inc. Electro Oceanics, Inc., has added a number of new lines to its "Watermate" series and Pelcon, Inc., has developed a new line of inductive couplers of reduced bulk and greater variety. Vector Cable has done considerable research and development on a new co-polymer bonding technique and is now offering connectors that feature ethylene/propylene co-polymer bonds to elastomers and polyurethane. D.G. O'Brien has a new series of fluid-filled electrical cable assemblies and connectors, with breakouts and adaptors, and Rochester/Brantner has expanded its standard line of pressure-balanced oil-filled connectors. ITT Cable-Hydrospace has been conducting research in fiber optics and is now offering, in addition to its standard line of connectors, fiber-optic cables, and terminations for single fibers and fiber bundles.

4.1.1 SCOPE

The object of this section is to present a representative listing of off-the-shelf underwater connectors available on the commercial market in order to assist the ocean engineer in identifying and selecting connectors for particular underwater applications. It includes (1) a consideration of some basic factors in connector design, drawn from references noted in the bibliography; (2) a brief discussion of connector classification; and (3) a standard product matrix form which classifies and describes common connector series that are available. The Master Catalogue which accompanies this manual should be consulted for additional manufacturer source information.

The matrices given in Section 4.4 represent only a portion of a given manufacturer's available connectors, since most manufacturers do 50-80% of their business in connectors of special design. Each matrix describes what is, in effect, a connector family, and represents a number of possible variations on the basic design. Information listed

in the matrices has been supplied by the manufacturers and should not be considered in any manner the result of an independent performance or specification investigation by the Applied Physics Laboratory. The primary object of the matrices is to identify the kinds of underwater electrical connectors that are available as off-the-shelf items, and to assist the prospective buyer in determining what his options are in terms of materials and design.

4.2 Critical Design Factors

Most connectors feature a number of basic components in common. These include (1) a housing, (2) electrical contacts, (3) electrical insulation, (4) termination and mating seals, and (5) strength member termination and strain relief. The specific designs of these components are varied and often considered proprietary, with the result that there are several thousand specific commercial connector models available. Recent materials studies and increased production experience have increased connector capabilities. Many connector models on the market have a good durability and pressure range and, when properly installed and maintained, can feasibly tolerate pressures up to 10,000 psi for a period of 10 years or more. However, as with all commercially supplied equipment, it remains advisable for the prospective buyer to familiarize himself with the specific design and materials of the connector he is considering and to form an independent judgment as to whether the connector will measure up to his specific requirements. Until such time as manufacturers establish and implement an industry standard of quality control, the buyer may need to take measures to protect quality in submarine connectors.

Basic design considerations are listed below and shown in Figure 4-1 (see also Reference 2).

1. Connector Types and Sizes
2. Plug Design
3. Receptacle Design
4. Pin and Socket Contact Design and Configuration
5. Fastening--Plug to Receptacle
6. Sealing--Plug to Receptacle
7. Connection--Conductor to socket Contact
8. Insulation and Seal--Pin Contact
9. Insulation and Seal--Socket Contact
10. Seal--Cable to Plug
11. Electrical Requirements
12. Cable Strain Relief
13. Material Selection
14. Corrosion Properties
15. Fabricability
16. Safety
17. Strength
18. Stiffness
19. Thermal Properties
20. Cost

Given a sound overall design, the importance of a single design factor may vary according to the requirements of the specific application that is under consideration. In general, long-term applications, high-stress applications, research applications and different electrical requirements not only dictate different connector designs, but also influence the choice of materials and the specifications for such factors as strength and thermal requirements. Generally, selection of a connector represents balancing desired characteristics and properties against inherent limitations in materials, design or performance.

4.2.1 THE HOUSING

Selection of housing materials (plug and receptacle) and coupling ring materials is one of the most important design considerations to be made. Commercial connector housings are generally available in a range of materials including rubber, plastics, special epoxies, stainless steel, titanium, brass and aluminum. Design considerations for the housing include the coupling arrangements between plug and receptacle and the mounting arrangements for bulkhead connectors. A coupling ring, often optional, is desirable since it provides additional strength; it should also facilitate mating and unmating. It is desirable that the receptacle be designed

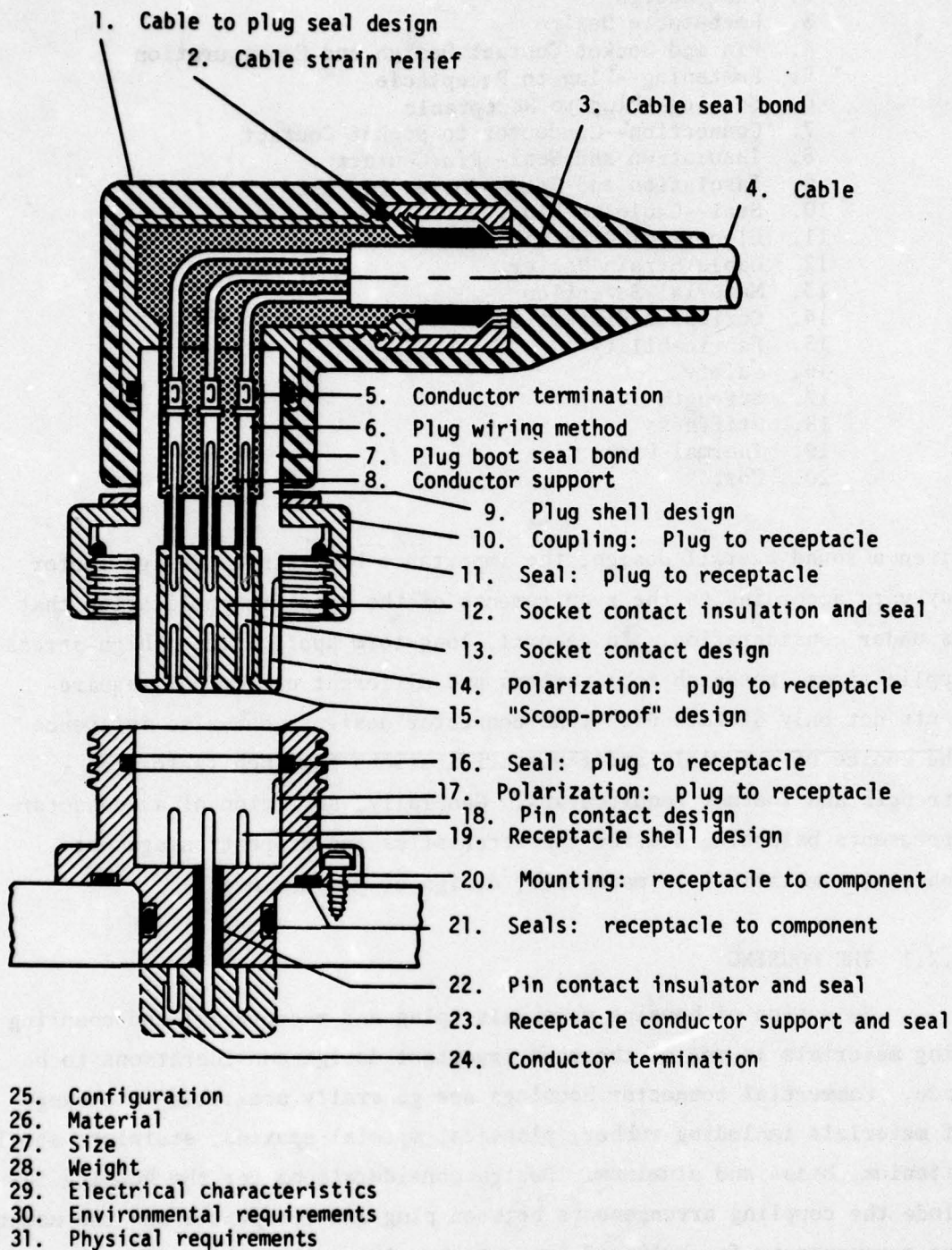


Figure 4-1. Underwater Electrical Connector Design Considerations.

so that the plug shell is not capable of striking the pin contacts when inserted off-axis. Polarization is another design consideration and may be important in preventing damage to the contacts and in providing phase-to-phase contact consistency. Additional considerations for housing design are its bondability to boot or potting, and provision for suitable strength termination shoulders for cable-to-connector termination, which generally represents the critical strength area of a system. The diametral requirements for connectors are generally dependent upon the size of the electrical contacts and the thickness of the housing, which is determined by the hydrostatic pressure requirements. The housing thickness also has the greatest effect upon connector weight. The housing material will need to meet corrosion, durability, strength, weight and cost requirements to the buyer's satisfaction.

4.2.2 ELECTRICAL CONTACTS

Electrical contact size and number are the most significant factors in determining overall connector size. Generally, contacts are also the significantly limiting factor in selecting off-the-shelf connectors due to the necessary standardization of contact numbers and sizes for a given connector series. While most manufacturers offer several options for contact numbers and sizes within a given connector series, these are often not acceptable to the buyer, who must then either make a special order, or modify his own size and number requirements. Available contact sizes generally range from #24 to #0000, and the number of contacts will range from one to 100+. They are available in several metals and alloys, usually gold or silver plated. Current ratings run from a few milliamperes to signals up to 200 amperes per phase. Maximum operating voltages are in the neighborhood of 1000 VAC. Most manufacturers also offer connector designs utilizing interchangeable contact inserts which seal to the housings and provide a positive waterblock. Contacts are also critical factors for high-current applications because of heating, for signal applications because of noise, and for high-voltage applications because of the need for long tracking paths on the adjacent insulation. Contact configuration and materials should provide inherent resistance to electrolytic corrosion resulting

from stray leakage current, since very slight differences in potential can erode metal sections in a very short period of time. At the rear of the plug and receptacle, the contacts should be embedded in a material of high bulk modulus and high compressive strength in order to provide support for contacts and conductors when they are subjected to high hydrostatic pressure loading. The transition from the pins and sockets of the contacts to the conductor is a critical design area and requires support to prevent kinking and possible fracture. Actual termination of contact to conductor is accomplished with sockets, crimping pots and solder pots.

4.2.3 ELECTRICAL INSULATION

Electrical insulation in underwater connectors normally serves not only as a dielectric, but also as a support against hydrostatic pressure that may be transmitted through the cable and plug assembly, and as a seal in the event of cable or connector damage. It should thus combine good dielectrical, strength and water-resisting properties. In most commercial molded systems, insulation is either neoprene rubber or glass-filled epoxy, while high-pressure systems may use fused glass and ceramics. A highly reliable system is also found in the pressure balanced systems utilizing a liquid dielectric which usually has good thermal properties, minimal compressibility, resistance to high-voltage tracking effects, and long-term durability. One of the most effective, and costly, combination insulation/seals is the hermetic seal, utilizing compression glass sealing for the contacts (MIL-C-22539, MIL-C-22249, MIL-C-24217 connector specifications).

4.2.4 CABLE TO PLUG/RECEPTACLE SEALS AND MATING SEALS

Boot seals for cable to plug/receptacle terminations are widely used in the connector industry, including bonded boots, compression molded boots and boots utilizing an automatic interference fit seal. Although jam grommets and O-ring gaskets are usually used in combination with boots, they are sometimes used alone to seal the cable-to-connector area. Boots provide additional cable strain relief and, when bonded

to the cable and plug body, provide one of the most reliable termination seals available. Potting and molding with urethane compounds is a frequent technique, and bonds of neoprene to stainless steel are also available. Additional techniques include polyethylene injection-molded cable seals to polyethylene-jacketed cable. Bonding techniques are undergoing substantial development in the connector industry at present with at least one manufacturer now offering ethylene or propylene copolymer bonding to elastomers and polyurethane.

Generally, the O-ring is a standard application for sealing the plug to the receptacle and the receptacle to the bulkhead for hull penetration. Redundant O-rings are available for some commercial connector series and are often sought for increased connector reliability.

4.2.5 STRENGTH MEMBER TERMINATION AND STRAIN RELIEF

The cable-to-connector area is one of the most critical areas in connector design. This termination area generally represents the weakest strength area of the cable system and it is necessary to carefully consider and specify general termination strength requirements when ordering commercial connectors. Termination strength is generally determined both by the tensile strength of connector materials and by the termination design at the rear of both plug and receptacle. Rubber molded connectors provide the least strength while metal connectors generally provide the greatest. Elaborate termination designs may be found in a number of the more complicated and reliable connector systems. However, even the glass-filled epoxy connectors may be expected to provide terminations that will resist 2,000 pounds of pull. Strength termination has numerous design possibilities, generally utilizing termination shoulders, flared-armour and cone, or a swagged ball for center strength members.

Cyclic hydrostatic pressure loading may result in Z kinking and fracture of conductors inside the plug shell area. Epoxy compounds provide good structural support for conductors, and cable strain relief may be accomplished with a number of devices, including grommets, compression molding, clamps, preformed grips and Kellam's grips.

4.3 Connector Classification

Connector classification raises certain problems due to the variety of critical factors in underwater connector design, any single one of which might conceivably be used as the basis for a classification system. Manufacturers use a range of criteria in organizing their connector catalogues, some of them arranging according to Mil-Spec criteria, others classifying according to materials, sizes or electrical characteristics.

Generally, the shell or molding material appears to be the most widely accepted and helpful method of classification, since a knowledge of the materials gives a good indication of corrosion, strength, cost, installation and sealing factors for a given connector.

The classification adopted for this manual section is listed in Table 4-1. Note that the last three classes are not according to materials but represent designs of sufficient uniqueness to warrant a special classification.

Table 4-1. Connector Classes

- | | |
|---|-------|
| 1. Molded Rubber Assemblies..... | RM |
| 2. Molded Plastic Assemblies..... | PM |
| 3. Metal Shell Assemblies..... | MS |
| 4. Pressure-Balanced, Oil-filled Assemblies.. | PBOF |
| 5. Underwater Mateables..... | UM |
| 6. Miscellaneous..... | Misc. |

4.3.1 MOLDED RUBBER ASSEMBLIES (RM)

The molded rubber connector is essentially a cable length with its conductors terminated with male or female contacts. The entire length is molded or cast to the cable jacket. The molded area provides a sealing interface between plug and receptacle, and also provides for strain transition between contact area and cable. Polarization is normally accomplished by contact pattern, polarizing pins or

varying contact diameters. When polarizing pins are not used, the RM connector is vulnerable to electrical mismatching and contact damage. Generally, RM connectors are available only in simple contact arrangements.

In fabricating the RM connector, neoprene is most often used for pressure molding and polyurethane for cast molding. Inability to properly control movement of the conductor during the pressure molding process can lead to broken circuits and electrical shorts that occur after the connector is situated in the operating environment. This may seriously affect reliability.

The RM connector, not having a rigid internal or external structure, does not provide for positive and controlled compression of interfacial seals. Most RM coupling and mounting devices are marginal because the material is subject to compression set. Low temperatures also affect the sealing mechanism due to loss of elasticity, and most RM designs have little or no protection for pin contacts.

Significant advantages are found, however, in the RM connector's low cost, light weight, resistance to abuse and in the simplicity of its sealing design. No significant corrosion problem exists. The dielectric qualities of elastomers preclude their contributing to galvanic corrosion of adjacent areas. Also, insulation is an integral function of the RM design. Material resilience provides for a void-free interface between the mated plug and receptacle.

4.3.2 MOLDED PLASTIC ASSEMBLIES (PM)

The PM connector comes in resin or epoxy materials, most of which are reinforced with glass and various fibers. They are relatively inexpensive and ideally suited to production in quantity. They incorporate a number of advantages of the RM connector, including a simple design that requires no internal seals, and an integral structural and dielectric material that is not affected by salt water corrosion and will not form a galvanic couple to damage adjacent metal parts. Their greatly increased strength provides an advantage over RM connectors; however, they are more brittle.

Plastics have several deficiencies as a connector fabricating material. Some thermosetting or thermoplastic materials do not appear to combine desirable electrical properties with all the required physical and mechanical properties necessary for use a deep submergence connectors. Desirable mechanical and physical properties include a high degree of dimensional stability, high impact strength, low mold shrinkage, low water absorption, high-compressive strength and nonflammability. Fabrication requirements further limit material choice. These requirements include good moldability at reasonable temperatures and pressures when using any necessary reinforcing fiber.

Some of the more common defects found in PM connector parts include the following: Cracks at points of high stress which are generated in the molding process and proliferate with use; threads that fail under load or are damaged by impact; failure in areas that are rich in mold resin and lack the necessary fiber content; seal surfaces that do not present the required finish due to excessive flash or porosity. PM connectors exposed to higher levels of pressure cycling have shown evidence of minute fiber displacement followed by fatigue and eventual structural failure. In addition, the effectiveness of the cable-to-connector seal may be limited by bondability and by cable temperature restrictions.

4.3.3 METAL SHELL ASSEMBLIES (MS)

Metal shell construction provides substantial rigidity and is generally considered to be the most reliable of underwater designs. However, it is of a more complex design, and is heavier and more costly. Reliability and resistance to handling and environmental damage may more than compensate for its disadvantages. Added initial cost may become insignificant when compared to overall system cost, given the critical role the connector plays in the system. Connector failures not only may render entire systems inoperable, but they may cause extensive damage to equipment, as well.

The metal plug shell provides a rigid and adequate bonding surface for the cable seal and thus provides adequate cable strain relief at this point. The rigid construction makes possible a greater degree of wire position control in molding a cable to the plug, and therefore much less chance of electrical shorts or open circuits due to uncontrolled migration of conductors during the cable end sealing process. The metal shell provides a positive stop for controlled gasket squeeze in seal areas between plug and receptacle and between receptacle and mounting surface. Metal has the necessary strength and dimensional stability to provide reliable threaded parts. A metal receptacle shell provides the necessary support for a positive and reliable pressure barrier in case of accidental exposure to sea pressure. Metal construction provides for a more reliable mounting of bulkhead types and an additional mounting method--a seal weld. An individual insulator in combination with snap-in socket contacts provides good contact positioning with adequate flotation for proper mating alignment. Metal bodies are best adapted for a positive keying arrangement to polarize plug with receptacle. Where both plug and receptacle shell are of a non-resilient material, a more reliable coupling can be accomplished. Elastomer compression set and material flow with resulting loosening is not a problem.

Disadvantages of the metal-type connector include the need for additional individual contact seals which are inherent in the integrally molded rubber-type connector. Sealing surfaces are subject to damage causing possible seal failure. Metal parts are subject to varying degrees of corrosion depending on material choice and environment. This condition can be compounded by other interfacing metals and/or stray electrical currents.

Insulating components must be provided for electrical isolation of the conductors. Means of securing and sealing these parts must also be provided. Applications that require the metal connector to be subjected to a considerable degree of pressure cycling call for special attention to the manner of wiring and how the conductors are supported

in the back end of the plug between the cable end seal and conductor termination. Otherwise, fatigue failure of the conductor can occur. Where nonresilient parts interface at plug and receptacle, a minimum volume void is always present because necessary dimensional tolerances preclude interfacial contact at this point. This void can cause some electrical degradation due to condensation of moisture in the contact area. This degradation can be significant depending on application and environmental temperature and humidity ranges. Contact insulation composed of compression glass seals must be adequately protected from welding temperatures when components are fastened or sealed by this method.

4.3.4 PRESSURE-BALANCED OIL-FILLED ASSEMBLIES (PBOF)

The PBOF connector, utilizing a metal shell and a liquid dielectric, is another highly reliable but costly connector. It is similar in many ways to the MS connector, but eliminates the need for potting, and the liquid filling provides void-free support against high pressure. Generally it is easier to assemble in the field since no potting is required. When assembled, the connector interface O-ring seal functions primarily to restrict oil leakage, since pressures inside and outside the connector are balanced. If the cable jacket is cut after application, the system continues to operate for a considerable period of time until the oil is forced out.

4.3.5 UNDERWATER MATEABLE ASSEMBLIES (UM)

Commercial UM connectors may be fabricated from any of the previously listed materials; they come in a variety of shapes, sizes and price ranges. Although some of them have been available on the commercial market for more than 10 years, they continue to undergo substantial research and development. Included in this class of connectors are the inductive couplers which are essentially transformers.

4.4 Connector Matrices

The matrix form used in this section is designed to furnish a quick comparative guide to commercial connectors of various classes by summarizing 35 design items for each of the connector series treated. Not every connector on the market is treated, since such an undertaking would result in a multi-volume work; however, the basic and significant connector families that manufacturers wish to identify as their standard products are represented with as much information as could be assembled about them. These matrices should furnish the prospective buyer with comparative profiles of similar products. After studying the matrices, the next step would be to consult the section of the Master Catalogue listed in the lower right-hand corner of each matrix for additional diagrams, dimensions and source information. Additional manufacturer information, including a listing of company addresses and phone numbers, as well as a summary of product users being undertaken by each company, is given in Section 5 of this manual. To facilitate updating, the matrices are not numbered.

4.4.1 MATRIX DISCLAIMER

The information contained in the list of matrices which follows has been supplied by product manufacturers as the result of a mail survey conducted during the first half of 1976. The Applied Physics Laboratory has neither validated nor investigated the claims of manufacturers, other than to check the information supplied in the questionnaires against the information contained in a given company's catalogue. Inclusion of a product in the matrices in no way constitutes a recommendation for its use by APL. Any omissions of manufacturers or their products are due either to an inability to identify and locate them, or an inability to acquire the necessary information.

4.5 References

1. Haworth, J., et al. Handbook of Vehicle Electrical Penetrators, Connectors, and Harnesses for Deep Ocean Applications; NTIS No. AD-888-281, July 1971.
2. Thomas, J.F., "A Study of Cable, Connector, and Penetrator Specifications," Naval Ship Research and Development Laboratory, Annapolis, Maryland, ATD-14, 1969.
3. Wilson, Jeffrey V., "General Technology Review of Electrical/Electromechanical Cable Connections in Ocean Systems," Naval Civil Engineering Laboratory, Port Hueneme, California, L43/JVW/1h, 1973.

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **RM**

STANDARD MATERIALS

Shell	Molded Neoprene
Boot/Jacket	
Contacts & Plating	Brass
Insulator	Neoprene
Coupling Ring/Nut	

CONNECTOR SIZE

Max. Length (Assembled)	
Maximum Diameter*	.812" to 1.38"

CONTACTS

Termination (Cable to Contact)	Crimp
Size Range	16, 12
Number Range	2-8

SEALING DESIGNS

Plug to Receptacle	Peripheral Seal
Cable to Plug	Boot
Contact Seal	
Receptacle to Bulkhead	O-ring

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	
Working Voltage	600 volts
Withstanding Voltage	1000 V ac
Contact Resistance	

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	20,000 psi
Unmated	
Temperature Range	
Durability:	
Number of Cycles	
Expected Life	
Vibration	
Physical Shock	
Corrosion	

POLARIZING METHOD

Visual

STRAIN RELIEF METHODS

Between Cable & Assembly:

Between Contacts & Wire:

SPECIAL DESIGN FEATURES

SPECIAL OPTIONS

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

MANUFACTURER:

Burton Electrical Engineering

SERIES:

5000: Multi-contact

* Including Hex Nut or Coupling Ring

CATALOGUE
PAGE **iv**

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **RM**

STANDARD MATERIALS

Shell	Neoprene or S.S.
Boot/Jacket	
Contacts & Plating	Brass, Bronze - Gold plating, MIL-G-45204, Type-2, Class-2
Insulator	Electrical rubber and glass epoxy
Coupling Ring/Nut	

CONNECTOR SIZE

Max. Length (Assembled)	3-11/16" to 5-5/8"
Maximum Diameter*	3/16" to 1-1/16"

POLARIZING METHOD

Pins; external visuals to prevent cross-mating

CONTACTS

Termination (Cable to Contact)	Solder; crimp
Size Range	20, 16, 14, 10, 8, 6, 4, 0
Number Range	1-12

STRAIN RELIEF METHODS

Between Cable & Assembly:

Between Contacts & Wire:
Loops

SEALING DESIGNS

Plug to Receptacle	Molded O-rings
Cable to Plug	Bonded
Contact Seal	Bonded
Receptacle to Bulkhead	O-ring

SPECIAL DESIGN FEATURES

Locking Sleeve

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	7 to 200 amps
Working Voltage	300-600 V dc
Withstanding Voltage	Various
Contact Resistance	Various

SPECIAL OPTIONS

Single pigtails; right angle; dummies

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	0-20,000'
Unmated	
Temperature Range	-20°F to 200°F
Durability:	
Number of Cycles	
Expected Life	1-10 yr
Vibration	
Physical Shock	
Corrosion	

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

\$16.00 to \$60.00

MANUFACTURER:

Brantner/Rochester

SERIES:

VM, RM;
VMA, RMG; RMA; VMG; RMK; VMK

* Including Hex Nut or Coupling Ring

CATALOGUE
PAGE

iv

PRODUCT MATRIX

CONNECTOR CLASSIFICATION **RM**

STANDARD MATERIALS

Shell	Molded Neoprene
Boot/Jacket	Neoprene
Contacts & Plating	Copper Alloy - Gold
Insulator	Neoprene
Coupling Ring/Nut	Locking Delrin Sleeves

CONNECTOR SIZE

Max. Length (Assembled)	6"
Maximum Diameter*	1-3/8"

CONTACTS

Termination (Cable to Contact)	Crimp
Size Range	16, 12, 8, 4, 0
Number Range	1-8

SEALING DESIGNS

Plug to Receptacle	O-ring or inertia seal
Cable to Plug	Vulcanized neoprene
Contact Seal	Neoprene molding
Receptacle to Bulkhead	O-ring

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	6 to 200 amps
Working Voltage	300 V ac
Withstanding Voltage	600 V dc
Contact Resistance	50 milliohms

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	10,000 psi
Unmated	2,500 psi
Temperature Range	-40°F to 250°F
Durability:	
Number of Cycles	250
Expected Life	5 yr
Vibration	
Physical Shock	
Corrosion	

POLARIZING METHOD

Pins

STRAIN RELIEF METHODS

Between Cable & Assembly:
Molded Neoprene taper joint

Between Contacts & Wire:

SPECIAL DESIGN FEATURES

Locking sleeve; fine stranded conductor with Teflon insulation

SPECIAL OPTIONS

Materials options: buna, polyurethane, viton, silicone molding compounds; also brass, stainless and aluminum locking sleeves

RECOMMENDED ZONES OF APPLICATION

Electrical power and/or strong signal transmission

APPROXIMATE PRICE RANGE

\$20.00 to \$30.00

MANUFACTURER:

Glenair, Inc.

SERIES:

GL20-in-line

* Including Hex Nut or Coupling Ring

CATALOGUE PAGE **v**

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **RM**

STANDARD MATERIALS

Shell	
Boot/Jacket	Neoprene Molding Compound; Glass Epoxy
Contacts & Plating	Brass - Silver
Insulator	Kintec, Inc. K-500
Coupling Ring/Nut	Locking Sleeve in Nylon, S.S., Brass

CONNECTOR SIZE

Max. Length (Assembled)	1-1/2" to 3-1/2"
Maximum Diameter*	.38" to 1.58"

CONTACTS

Termination (Cable to Contact)	Solder
Size Range	20, 16, 14, 10, 8, 6, 0, 00 Coax
Number Range	1 to 8

SEALING DESIGNS

Plug to Receptacle	Redundant O-rings
Cable to Plug	Neopre., Plyuret. Mold
Contact Seal	Molding
Receptacle to Bulkhead	O-ring

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	0 to 600 amps
Working Voltage	to 15,000 V
Withstanding Voltage	2 x wkg. vltg. + 1000
Contact Resistance	.5 to .25 milliohms

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	10,000 psi
Unmated	10,000 psi
Temperature Range	to 400°F
Durability:	
Number of Cycles	
Expected Life	to 20 yr
Vibration	as required
Physical Shock	as required
Corrosion	as required

POLARIZING METHOD

Pins; keys; visual keys

STRAIN RELIEF METHODS

Between Cable & Assembly:

Hard Encapsulation

Between Contacts & Wire:

Hard Encapsulation

SPECIAL DESIGN FEATURES

Locking sleeves; removable contact inserts; right angle plugs.

SPECIAL OPTIONS

Receptacle available in glass epoxy; field-installable assemblies -- no molding req'd field-moldable assemblies; large O-ring; multi-wire termination; high voltage designs.

RECOMMENDED ZONES OF APPLICATION

Down-hole logging, deep ocean applications.

APPROXIMATE PRICE RANGE

\$50.00 to \$200.00

MANUFACTURER:

Kintec, Inc.

SERIES:

HS: HS1, HS2, HS4, HS6

* Including Hex Nut or Coupling Ring

CATALOGUE
PAGE **vi**

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **RM**

STANDARD MATERIALS

Shell	(P) Molded Elastomer; (R) Elastomer, S.S. or Brass
Boot/Jacket	Molded Neoprene
Contacts & Plating	Brass - Gold
Insulator	Electrical Grade Elastomers
Coupling Ring/Nut	Plastic, Brass, S.S.

CONNECTOR SIZE

Max. Length (Assembled)
Maximum Diameter*

POLARIZING METHOD

Pins; Keys

CONTACTS

Termination (Cable to Contact)	Solder
Size Range	20, 16, 12, 8, 4, 0
Number Range	1-8

STRAIN RELIEF METHODS

Between Cable & Assembly:
Molded taper
Between Contacts & Wire:
Molding

SEALING DESIGNS

Plug to Receptacle	O-ring
Cable to Plug	Molded
Contact Seal	Integrally molded
Receptacle to Bulkhead	O-ring

SPECIAL DESIGN FEATURES

Locking sleeve

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	5 to 200 amps
Working Voltage	600 V
Withstanding Voltage	1000 V
Contact Resistance	various

SPECIAL OPTIONS

Coax available; various contact arrangements on special order; right angle; pigtails

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	20,000 psi
Unmated	
Temperature Range	-20°F to 200°F
Durability:	
Number of Cycles	
Expected Life	
Vibration	
Physical Shock	
Corrosion	

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

Variable - relatively inexpensive

MANUFACTURER:

Vector Cable Co.

SERIES:

RM

* Including Hex Nut or Coupling Ring

CATALOGUE
PAGE **vii**

13

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **PM**

STANDARD MATERIALS

Shell	Delrin
Boot/Jacket	
Contacts & Plating	Copper Alloy - Silver
Insulator	Delrin
Coupling Ring/Nut	Delrin

CONNECTOR SIZE

Max. Length (Assembled)	6-1/8"
Maximum Diameter*	1-5/8"

CONTACTS

Termination (Cable to Contact)	Solder
Size Range	16, 10, 14
Number Range	1-7

SEALING DESIGNS

Plug to Receptacle	O-ring
Cable to Plug	Grommet Seals
Contact Seal	Delrin
Receptacle to Bulkhead	O-ring

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	7 to 15 amps
Working Voltage	300 V dc
Withstanding Voltage	1000 V dc
Contact Resistance	various

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	2500 psi
Unmated	
Temperature Range	0°F to 150°F
Durability:	
Number of Cycles	
Expected Life	
Vibration	
Physical Shock	
Corrosion	

POLARIZING METHOD

Pins; Keys

STRAIN RELIEF METHODS

Between Cable & Assembly:

Between Contacts & Wire:
Slack

SPECIAL DESIGN FEATURES

Field Installable; removable contact inserts

SPECIAL OPTIONS

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

\$30.00 to \$40.00

MANUFACTURER:

Brantner/Rochester

SERIES:

Hydrocon

* Including Hex Nut or Coupling Ring

CATALOGUE
PAGE **iv**

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **PM**

STANDARD MATERIALS

Shell	Glass Epoxy
Boot/Jacket	Neoprene or Polyurethane
Contacts & Plating	Brass or Bronze
Insulator	Glass Epoxy
Coupling Ring/Nut	Nylon or S.S.

CONNECTOR SIZE

Max. Length (Assembled)	3-1/2" to 11-1/2"
Maximum Diameter*	.93" to 2.2"

CONTACTS

Termination (Cable to Contact)	Solder
Size Range	20, 16, 14, 10, 8, 6
Number Range	1-24

SEALING DESIGNS

Plug to Receptacle	O-ring
Cable to Plug	Bonded Neoprene or boot
Contact Seal	Bonded Epoxy/Glass
Receptacle to Bulkhead	O-ring

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	3 to 45 amps
Working Voltage	300-600 V dc
Withstanding Voltage	Various
Contact Resistance	Various

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	0 - 20,000'
Unmated	13,500' (BCR only)
Temperature Range	-20°F to 200°F
Durability:	
Number of Cycles	
Expected Life	1-10 yr
Vibration	
Physical Shock	
Corrosion	

POLARIZING METHOD

Pins; Keys

STRAIN RELIEF METHODS

Between Cable & Assembly:

Between Contacts & Wire:
Loops and Epoxy

SPECIAL DESIGN FEATURES

Shielding device on XSJ only

SPECIAL OPTIONS

Right angles; single pigtails; slip-on boots, shield termination; field-installable; pressure-balanced oil-filled.

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

\$55.00 to \$220.00

MANUFACTURER:

Brantner/Rochester

SERIES:

VS, XS: XSJ, XSL, XSM

* Including Hex Nut or Coupling Ring

CATALOGUE
PAGE **iv**

PRODUCT MATRIX

CONNECTOR CLASSIFICATION **PM**

STANDARD MATERIALS

Shell	Glass Epoxy
Boot/Jacket	Molded Neoprene
Contacts & Plating	Copper Alloy - Gold
Insulator	Glass Epoxy
Coupling Ring/Nut	Delrin, Jam Nut: S.S.

CONNECTOR SIZE

Max. Length (Assembled)	3-1/4"
Maximum Diameter*	1-1/2"

CONTACTS

Termination (Cable to Contact)	Solder
Size Range	16
Number Range	6 and 8

SEALING DESIGNS

Plug to Receptacle	2 O-rings
Cable to Plug	Molded Neoprene
Contact Seal	Glass Epoxy
Receptacle to Bulkhead	O-ring

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	6 to 7.5 amps
Working Voltage	600 V dc
Withstanding Voltage	1000 V dc
Contact Resistance	50 milliohms

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	10,000 psi
Unmated	10,000 psi
Temperature Range	-67°F to 350°F
Durability:	
Number of Cycles	250
Expected Life	10 yr
Vibration	
Physical Shock	
Corrosion	

* Including Hex Nut or Coupling Ring

POLARIZING METHOD

Key

STRAIN RELIEF METHODS

Between Cable & Assembly:
Molded Neoprene
Between Contacts & Wire:

SPECIAL DESIGN FEATURES

Gold plated contacts with integral solder pots

SPECIAL OPTIONS

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

\$50.00

MANUFACTURER:

Glenair, Inc.

SERIES:

GL30L - Bulkhead

CATALOGUE PAGE **v**

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **PM**

STANDARD MATERIALS

Shell	Glass Epoxy
Boot/Jacket	
Contacts & Plating	Copper Alloy - Gold
Insulator	Glass Epoxy
Coupling Ring/Nut	Jam Nut: S.S.

CONNECTOR SIZE

Max. Length (Assembled)	1-3/4"
Maximum Diameter*	2"

CONTACTS

Termination (Cable to Contact)	Solder
Size Range	16, 12, 8, 4, 0
Number Range	1-8

SEALING DESIGNS

Plug to Receptacle	0-ring or inertia seal
Cable to Plug	
Contact Seal	Glass epoxy
Receptacle to Bulkhead	0-ring

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	6 to 200 amps
Working Voltage	300 V ac
Withstanding Voltage	1000 V dc
Contact Resistance	50 milliohms

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	10,000 psi
Unmated	10,000 psi
Temperature Range	-67°F to 350°F
Durability:	
Number of Cycles	500
Expected Life	10 yr
Vibration	
Physical Shock	
Corrosion	

* Including Hex Nut or Coupling Ring

POLARIZING METHOD

Pins

STRAIN RELIEF METHODS

Between Cable & Assembly:

Between Contacts & Wire:

SPECIAL DESIGN FEATURES

Large 0-ring wall

SPECIAL OPTIONS

Shell material may be stainless steel, brass or aluminum with molded-in neoprene insert

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

\$25.00 to \$40.00

MANUFACTURER:

Glenair, Inc.

SERIES:

GL30-Bulkhead

CATALOGUE
PAGE **v**

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **PM**

STANDARD MATERIALS

Shell	Glass Epoxy
Boot/Jacket	Vulcanized Neoprene
Contacts & Plating	Copper - Gold
Insulator	Glass Epoxy
Coupling Ring/Nut	Nylon

CONNECTOR SIZE

Max. Length (Assembled)	Approx. 3.750"
Maximum Diameter*	1.55"

CONTACTS

Termination (Cable to Contact)	Solder
Size Range	16
Number Range	6-10

SEALING DESIGNS

Plug to Receptacle	O-ring
Cable to Plug	Vulcanized Neoprene
Contact Seal	Molded Epoxy
Receptacle to Bulkhead	1-2 O-rings

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	6 amps
Working Voltage	500 V dc
Withstanding Voltage	1000 V ac
Contact Resistance	

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	20,000 psi
Unmated	20,000 psi
Temperature Range	
Durability:	
Number of Cycles	
Expected Life	
Vibration	
Physical Shock	
Corrosion	

POLARIZING METHOD

Key

STRAIN RELIEF METHODS

Between Cable & Assembly:

Between Contacts & Wire:

SPECIAL DESIGN FEATURES

SPECIAL OPTIONS

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

\$80.00 to \$90.00

MANUFACTURER:

Gould, Inc.

SERIES:

CX-106B, CX-108B; CX-106P, CX-108P

* Including Hex Nut or Coupling Ring

CATALOGUE
PAGE

V

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **PM**

STANDARD MATERIALS

Shell	
Boot/Jacket	Glass Epoxy or Neoprene Molding Compound
Contacts & Plating	Brass - Silver
Insulator	Kintec, Inc. K-500
Coupling Ring/Nut	Nylon

CONNECTOR SIZE

Max. Length (Assembled)	2.58" to 11.50"
Maximum Diameter*	1.5"

CONTACTS

Termination (Cable to Contact)	Solder
Size Range	16
Number Range	6, 8, 10

SEALING DESIGNS

Plug to Receptacle	Redundant O-ring
Cable to Plug	Neopre., Plyuret.Mold
Contact Seal	Molding
Receptacle to Bulkhead	O-ring

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	0 to 600 amps
Working Voltage	to 15,000 V
Withstanding Voltage	2 x wkg. vltg. + 1000
Contact Resistance	.5 to .25 milliohms

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	10,000 psi
Unmated	10,000 psi
Temperature Range	to 400°F
Durability:	
Number of Cycles	
Expected Life	to 20 yr
Vibration	as required
Physical Shock	as required
Corrosion	as required

POLARIZING METHOD

Keys

STRAIN RELIEF METHODS

Between Cable & Assembly:
Hard Encapsulation

Between Contacts & Wire:
Hard Encapsulation

SPECIAL DESIGN FEATURES

Locking Sleeve

SPECIAL OPTIONS

Multi-wire termination;
right-angle plug;
field-installable assemblies

RECOMMENDED ZONES OF APPLICATION

Down-hole logging;
deep ocean applications

APPROXIMATE PRICE RANGE

\$190.00 to \$300.00

MANUFACTURER:

Kintec, Inc.

SERIES:

NM 10

* Including Hex Nut or Coupling Ring

CATALOGUE
PAGE **vi**

PRODUCT MATRIX

CONNECTOR CLASSIFICATION **PM**

STANDARD MATERIALS

Shell
Boot/Jacket
Contacts & Plating
Insulator
Coupling Ring/Nut

CONNECTOR SIZE

Max. Length (Assembled)
Maximum Diameter*

POLARIZING METHOD

Key

CONTACTS

Termination (Cable to Contact) Solder
Size Range
Number Range 3

STRAIN RELIEF METHODS

Between Cable & Assembly:
Cable Collet
Between Contacts & Wire:

SEALING DESIGNS

Plug to Receptacle 0-ring
Cable to Plug Grommet
Contact Seal
Receptacle to Bulkhead

SPECIAL DESIGN FEATURES

Field Repairable

ELECTRICAL CHARACTERISTICS

Max. Current Capacity
Working Voltage
Withstanding Voltage
Contact Resistance

SPECIAL OPTIONS

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:
Mated 500 psi
Unmated
Temperature Range
Durability:
Number of Cycles
Expected Life
Vibration
Physical Shock
Corrosion

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

MANUFACTURER:

Mark Products, Inc.

SERIES:

Amphib 3

* Including Hex Nut or Coupling Ring

CATALOGUE PAGE **vi**

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **PM**

STANDARD MATERIALS

Shell	Molded Plastic
Boot/Jacket	Various, depending on cable
Contacts & Plating	Brass - Gold
Insulator	Molded Glass Epoxy
Coupling Ring/Nut	Plastic, Brass, S.S.

CONNECTOR SIZE

Max. Length (Assembled)
Maximum Diameter*

POLARIZING METHOD

Pins; Keys

CONTACTS

Termination (Cable to Contact)	Solder
Size Range	20, 16, 12, 8, 4, 0
Number Range	1-36

STRAIN RELIEF METHODS

Between Cable & Assembly:

Between Contacts & Wire:

SEALING DESIGNS

Plug to Receptacle	1-2 O-rings
Cable to Plug	Molded
Contact Seal	Glass Epoxy
Receptacle to Bulkhead	1-2 O-rings

SPECIAL DESIGN FEATURES

Locking sleeve; hermetic pin seals

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	5 to 200 amps
Working Voltage	300-600 V (rms)
Withstanding Voltage	1500 V
Contact Resistance	Various

SPECIAL OPTIONS

Special contact patterns;
Special keying arrangements

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	20,000 psi
Unmated	20,000 psi
Temperature Range	up to 250°F
Durability:	
Number of Cycles	
Expected Life	
Vibration	
Physical Shock	
Corrosion	

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

Variable - relatively inexpensive

MANUFACTURER:

Vector Cable Co.

SERIES:

XS

* Including Hex Nut or Coupling Ring

CATALOGUE
PAGE **vii**

MS

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **MS**

STANDARD MATERIALS

Shell	(P) Aluminum - Anodic Coating; (R) S.S. Recep.
Boot/Jacket	S.S. Sleeve
Contacts & Plating	Copper Alloy - Gold (Hermetic; Ni-iron/gold)
Insulator	Neoprene
Coupling Ring/Nut	Aluminum Bronze

CONNECTOR SIZE

Max. Length (Assembled)	Approx. 2.5"
Maximum Diameter*	Approx. 2.26"

CONTACTS

Termination (Cable to Contact)	Solder; crimp
Size Range	20, 16, 12
Number Range	2#20 to 61#20

SEALING DESIGNS

Plug to Receptacle	O-ring
Cable to Plug	Molding
Contact Seal	Glass (hermetic only)
Receptacle to Bulkhead	O-ring

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	7.5 to 22 amps
Working Voltage	500 V ac (rms)
Withstanding Voltage	1,500 V ac (rms)
Contact Resistance	Max. 55 millivolt drop

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	0-1500 psi
Unmated	0-plug, 400-herm recep.
Temperature Range	-25°C to 100°C
Durability:	
Number of Cycles	500
Expected Life	5 yr
Vibration	MIL-C-26482
Physical Shock	MIL-C-26482
Corrosion	MIL-C-26482

POLARIZING METHOD

Keys; alternate keying positions available

STRAIN RELIEF METHODS

Between Cable & Assembly:
Molding

Between Contacts & Wire:
Hard epoxy potting (recommended)

SPECIAL DESIGN FEATURES

5 key polarization; threaded coupling; MS arrangements and contacts; MS crimping tools

SPECIAL OPTIONS

Pressure-proof caps, accessory threads on plug and receptacle, use with MS-EMR hardware, potting boot and ring. Nonmagnetic hermetic contacts.

RECOMMENDED ZONES OF APPLICATION

0-1500 psi

APPROXIMATE PRICE RANGE

Widely variable

MANUFACTURER:

Bendix Electrical Components Division

SERIES:

AP Aquacon Series

* Including Hex Nut or Coupling Ring

CATALOGUE
PAGE

iv

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **MS**

STANDARD MATERIALS

Shell	(P) Aluminum - Anodic Coating; (R) S.S.
Boot/Jacket	S.S. Sleeve
Contacts & Plating	Copper Alloy - Gold; (Hermetic: Ni-Iron/Gold)
Insulator	Glass-filled epoxy; (Hermetic: Glass)
Coupling Ring/Nut	Aluminum Bronze

CONNECTOR SIZE

Max. Length (Assembled)	Approx. 2.0"
Maximum Diameter*	Approx. 2.25"

CONTACTS

Termination (Cable to Contact)	Solder; Crimp
Size Range	22D, 20, 16, 12
Number Range	3#20 to 128#22

SEALING DESIGNS

Plug to Receptacle	O-ring
Cable to Plug	Molding
Contact Seal	Glass (Hermetic only)
Receptacle to Bulkhead	O-ring

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	3 to 23 amps
Working Voltage	400-900 V ac (rms)
Withstanding Voltage	1300 V ac (rms)
Contact Resistance	85 millivolt drop

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	0-1500 psi
Unmated	0-plug; 400 herm. receptacle
Temperature Range	-25°C to 100°C
Durability:	
Number of Cycles	500
Expected Life	5 yr
Vibration	MIL-C-38999
Physical Shock	MIL-C-38999
Corrosion	MIL-C-38999

* Including Hex Nut or Coupling Ring

POLARIZING METHOD

Keys; alternate keying positions available

STRAIN RELIEF METHODS

Between Cable & Assembly:
Molding
Between Contacts & Wire:
Hard epoxy, potting (recommended)

SPECIAL DESIGN FEATURES

Removable Contacts; 5 key polarization; threaded coupling; MIL-C-38999 Insert Arrangements and Contacts; MS crimping tools

SPECIAL OPTIONS

Pressure-proof caps; accessory threads on plug and receptacle; use with MS-EMR hardware, potting boot and ring nonmagnetic hermetic contacts; 5000 psi openface pressure for hermetic receptacle.

RECOMMENDED ZONES OF APPLICATION

0-1500 psi

APPROXIMATE PRICE RANGE

Widely variable

MANUFACTURER:

Bendix Electrical Components Division

SERIES:

AJ Aquacon Series

CATALOGUE
PAGE **iv**

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **MS**

STANDARD MATERIALS

Shell	(P) Aluminum-Anodic Coating; (R) S.S.
Boot/Jacket	S.S. Sleeve
Contacts & Plating	Copper Alloy - Gold; (Hermetic: Ni-Iron/Gold)
Insulator	Glass filled epoxy; (Hermetic: glass)
Coupling Ring/Nut	

CONNECTOR SIZE

Max. Length (Assembled)	Approx. 3.25"
Maximum Diameter*	Approx. 2.25"

CONTACTS

Termination (Cable to Contact)	Solder; Crimp
Size Range	22D, 20, 16, 12
Number Range	3#20 to 128#22

SEALING DESIGNS

Plug to Receptacle	O-ring
Cable to Plug	Molding
Contact Seal	Glass (Hermetic only)
Receptacle to Bulkhead	O-ring

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	3 to 23 amps
Working Voltage	400-900 V ac (rms)
Withstanding Voltage	1300 V ac (rms)
Contact Resistance	60-85 mV drop, max.

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	0-1500 psi
Unmated	(P) 0 psi; (R) 400 psi
Temperature Range	-25°C to 100°C
Durability:	
Number of Cycles	500
Expected Life	5 yr
Vibration	MIL-C-38999
Physical Shock	MIL-C-38999
Corrosion	MIL-C-38999

* Including Hex Nut or Coupling Ring

POLARIZING METHOD

Keys; alternate keying positions available

STRAIN RELIEF METHODS

Between Cable & Assembly:
Molding
Between Contacts & Wire:
Hard epoxy potting (recommended)

SPECIAL DESIGN FEATURES

5 key polarization; scoop-proof; threaded coupling; MIL-C-38999 inset arrangements and contacts; MS crimping tools

SPECIAL OPTIONS

Pressure-proof caps; accessory threads on plug and receptacle; use with MS-EMR hardware; potting boot and ring; nonmagnetic hermetic contacts; 5000 psi openface pressure (hermetic)

RECOMMENDED ZONES OF APPLICATION

0-1500 psi

APPROXIMATE PRICE RANGE

Widely variable

MANUFACTURER:

Bendix Electrical Components Division

SERIES:

AS Aquacon Series

CATALOGUE
PAGE **iv**

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **MS**

STANDARD MATERIALS

Shell	(P) Aluminum-Anodic Coating; (R) S.S.
Boot/Jacket	S.S. Sleeve
Contacts & Plating	Copper Alloy/Gold; (Hermetic: Ni-Iron/Gold)
Insulator	Glass filled epoxy; (Hermetic: Glass)
Coupling Ring/Nut	Aluminum Bronze

CONNECTOR SIZE

Max. Length (Assembled)	Approx. 3.0"
Maximum Diameter*	Approx. 2.25"

CONTACTS

Termination (Cable to Contact)	Solder; Crimp
Size Range	22D, 20, 16, 12
Number Range	3#20 to 128#22

SEALING DESIGNS

Plug to Receptacle	O-ring
Cable to Plug	Molding
Contact Seal	Glass (hermetic only)
Receptacle to Bulkhead	O-ring

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	3 to 23 amps
Working Voltage	400-900 V ac (rms)
Withstanding Voltage	1300 V ac (rms)
Contact Resistance	60-85 mV drop

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	0-1500 psi
Unmated	(P) 0 psi, (R-herm) 400
Temperature Range	-25°C to 100°C
Durability:	
Number of Cycles	500
Expected Life	5 yr
Vibration	MIL-C-38999
Physical Shock	MIL-C-38999
Corrosion	MIL-C-38999

POLARIZING METHOD

Keys; alternate keying positions available

STRAIN RELIEF METHODS

Between Cable & Assembly:
Molding

Between Contacts & Wire:
Hard epoxy potting (recommended)

SPECIAL DESIGN FEATURES

5 key polarization; scoop-proof; threaded coupling; MIL-C-38999 insert arrangements and contacts; MS crimping tools

SPECIAL OPTIONS

Pressure-proof caps; accessory threads on plug and receptacle, use with MS-EMR hardware, potting boot and ring, nonmagnetic hermetic contacts, 5000 psi open-face pressure (hermetic)

RECOMMENDED ZONES OF APPLICATION

0-1500 psi

APPROXIMATE PRICE RANGE

Widely variable

MANUFACTURER:

Bendix Electrical Components Division

SERIES:

AL Series Aquacon

* Including Hex Nut or Coupling Ring

CATALOGUE
PAGE **iv**

PRODUCT MATRIX

CONNECTOR CLASSIFICATION **MS**

STANDARD MATERIALS

Shell	S.S.
Boot/Jacket	Neoprene
Contacts & Plating	Copper Alloy
Insulator	Neoprene
Coupling Ring/Nut	S.S.

CONNECTOR SIZE

Max. Length (Assembled)	
Maximum Diameter*	3.81"

CONTACTS

Termination (Cable to Contact)	Crimp
Size Range	12,16
Number Range	1-60

SEALING DESIGNS

Plug to Receptacle	Peripheral Seal
Cable to Plug	Integrally Molded
Contact Seal	Molded Insulator
Receptacle to Bulkhead	O-ring

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	5 to 150 amps
Working Voltage	625 V ac
Withstanding Voltage	1250 V ac
Contact Resistance	Typ. 50 milliohms

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	10,000 psi
Unmated	10,000 psi
Temperature Range	-65°F to 165°F
Durability:	
Number of Cycles	500
Expected Life	
Vibration	MIL-STD-202(202-A)
Physical Shock	MIL-STD-202(207)
Corrosion	

POLARIZING METHOD

Pins; Keys

STRAIN RELIEF METHODS

Between Cable & Assembly:
Armor for High Strength; molding

Between Contacts & Wire:
Molding and Potting

SPECIAL DESIGN FEATURES

Shielding device; Acme threads; individual contact seals

SPECIAL OPTIONS

RECOMMENDED ZONES OF APPLICATION

General Undersea

APPROXIMATE PRICE RANGE

\$35.00 to \$200.00

MANUFACTURER:

Boston Insulated Wire and Cable Company

SERIES:

Type EB Underwater Connector Series

* Including Hex Nut or Coupling Ring

CATALOGUE PAGE **iv**

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **MS**

STANDARD MATERIALS

Shell	S.S.
Boot/Jacket	Neoprene
Contacts & Plating	Copper Alloy
Insulator	Neoprene
Coupling Ring/Nut	S.S.

CONNECTOR SIZE

Max. Length (Assembled)	12"
Maximum Diameter*	3"

CONTACTS

Termination (Cable to Contact)	Solder
Size Range	16, 14, 12, 1, 00
Number Range	3-28

SEALING DESIGNS

Plug to Receptacle	Peripheral seal
Cable to Plug	Integrally molded
Contact Seal	Interlocking cones
Receptacle to Bulkhead	O-ring

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	5 to 150 amps
Working Voltage	600 to 3,000 V ac
Withstanding Voltage	2,200 to 10,000 V ac
Contact Resistance	Typ. 50 milliohms

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	10,000 psi
Unmated	10,000 psi
Temperature Range	-55°F to 165°F
Durability:	
Number of Cycles	500
Expected Life	
Vibration	MIL-STD-202(202-A)
Physical Shock	MIL-STD-202(207)
Corrosion	

POLARIZING METHOD

Pins; Keys

STRAIN RELIEF METHODS

Between Cable & Assembly:
Armor for high strength; molding for low strength
Between Contacts & Wire:
Molding and potting

SPECIAL DESIGN FEATURES

Shielding device; removable contact inserts; stub Acme threads; individual contact seals

SPECIAL OPTIONS

RECOMMENDED ZONES OF APPLICATION

General Undersea

APPROXIMATE PRICE RANGE

\$35.00 to \$200.00

MANUFACTURER:

Boston Insulated Wire and Cable Co.

SERIES:

Type ER Underwater Connector Series

* Including Hex Nut or Coupling Ring

CATALOGUE
PAGE **iv**

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **MS**

STANDARD MATERIALS

Shell	316 S.S. - QQS-763
Boot/Jacket	Neoprene, Polyurethane, Polyethylene
Contacts & Plating	Brass, Bronze & Copper Alloy - Gold Plating, MIL-G-45204, Type 2, Class 2
Insulator	Epoxy Glass
Coupling Ring/Nut	NIALBRO-QQB-679

CONNECTOR SIZE

Max. Length (Assembled)	7" to 33"
Maximum Diameter*	1.37" to 3.87"

CONTACTS

Termination (Cable to Contact)	Solder
Size Range	20, 16, 14, 10, 8, 6, 4, 0
Number Range	Coax-108

SEALING DESIGNS

Plug to Receptacle	0-ring
Cable to Plug	Neoprene & Polyurethane bonding
Contact Seal	Epoxy/Glass bonding
Receptacle to Bulkhead	0-rings/welding

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	3 to 200 amps
Working Voltage	300 V dc
Withstanding Voltage	5000 V dc
Contact Resistance	various

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	0-20,000'
Unmated	13,500'
Temperature Range	-20°F to 350°F
Durability:	
Number of Cycles	
Expected Life	1-20 yr
Vibration	
Physical Shock	
Corrosion	

POLARIZING METHOD

Pins; Keys

STRAIN RELIEF METHODS

Between Cable & Assembly:

Between Contacts & Wire:

Loops & Epoxy

SPECIAL DESIGN FEATURES

Shielding device; removable contact inserts

SPECIAL OPTIONS

Single pigtails; right angle; flange mounts; double armored cable termination; pressure-balanced oil-filled; dummies; shells in alum, brass, Inconel; Kelvar termination

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

\$200.00 to \$655.00

MANUFACTURER:

Brantner/Rochester

SERIES:

MS, MSS

* Including Hex Nut or Coupling Ring

CATALOGUE
PAGE **iv**

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **MS**

STANDARD MATERIALS

Shell	S.S., Passivated
Boot/Jacket	
Contacts & Plating	
Insulator	
Coupling Ring/Nut	
	Molded Neoprene & Thermosetting Plastic
	S.S.

CONNECTOR SIZE

Max. Length (Assembled)	
Maximum Diameter*	1.125" to 2.750"

CONTACTS

Termination (Cable to Contact)	Crimp
Size Range	16, 12, 8, 4, 0, 0000
Number Range	1-52

SEALING DESIGNS

Plug to Receptacle	
Cable to Plug	
Contact Seal	
Receptacle to Bulkhead	O-ring

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	4-300 amps
Working Voltage	600 volts
Withstanding Voltage	
Contact Resistance	

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	10,000 psi
Unmated	
Temperature Range	
Durability:	
Number of Cycles	
Expected Life	
Vibration	
Physical Shock	
Corrosion	

POLARIZING METHOD

STRAIN RELIEF METHODS

Between Cable & Assembly:

Between Contacts & Wire:

SPECIAL DESIGN FEATURES

Pigtails (MIL-W-16878)

SPECIAL OPTIONS

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

MANUFACTURER:

Burton Electrical Engineering

SERIES:

5400: Feedthru Assemblies

* Including Hex Nut or Coupling Ring

CATALOGUE
PAGE **iv**

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **MS**

STANDARD MATERIALS

Shell	S.S., Passivated
Boot/Jacket	Molded Neoprene
Contacts & Plating	Brass
Insulator	Molded Neoprene and Thermosetting Plastic
Coupling Ring/Nut	S.S.

CONNECTOR SIZE

Max. Length (Assembled)	
Maximum Diameter*	1.10" to 2.25"

CONTACTS

Termination (Cable to Contact)	Crimp
Size Range	18, 16, 14, 12, 8
Number Range	2-24

SEALING DESIGNS

Plug to Receptacle	Peripheral, inter- facial
Cable to Plug	Molded Boot
Contact Seal	
Receptacle to Bulkhead	O-ring

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	4-50 amps
Working Voltage	600 volts
Withstanding Voltage	MIL-C-24217 (4.7.3)
Contact Resistance	MIL-C-22857

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure, Range:	
Mated	MIL-C-24217 (4.7.6)
Unmated	MIL-C-24217 (4.7.6)
Temperature Range	MIL-C-24217 (4.7.7)
Durability:	
Number of Cycles	MIL-C-24217 (4.7.4)
Expected Life	
Vibration	
Physical Shock	
Corrosion	

POLARIZING METHOD

Keys

STRAIN RELIEF METHODS

Between Cable & Assembly:
Cable Flexing: MIL-C-24217 (4.7.5)
Between Contacts & Wire:

SPECIAL DESIGN FEATURES

Pigtails

SPECIAL OPTIONS

Panel Mounting Receptacle

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

MANUFACTURER:

Burton Electrical Engineering

SERIES:

5500 and 5600

* Including Hex Nut or Coupling Ring

CATALOGUE
PAGE **iv**

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **MS**

STANDARD MATERIALS

Shell	316 S.S., Passivated
Boot/Jacket	Neoprene
Contacts & Plating	Steel Alloy - Gold Plating
Insulator	Compression Glass Integral with Shell
Coupling Ring/Nut	S.S.

CONNECTOR SIZE

Max. Length (Assembled)	
Maximum Diameter*	1.900" to 3.125"

CONTACTS

Termination (Cable to Contact)	Crimp
Size Range	16, 12, 8, 4, 0, 0000
Number Range	1-48

SEALING DESIGNS

Plug to Receptacle	0-ring, Interfacial
Cable to Plug	Molded Boot
Contact Seal	Compression Glass
Receptacle to Bulkhead	0-rings (2)

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	13 amps @ 625 V rms
Working Voltage	625 V rms
Withstanding Voltage	MIL-C-24217
Contact Resistance	

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	
Unmated	
Temperature Range	Meets all MIL-C-24217 performance requirements.
Durability:	
Number of Cycles	
Expected Life	
Vibration	
Physical Shock	
Corrosion	

* Including Hex Nut or Coupling Ring

POLARIZING METHOD

Keys

STRAIN RELIEF METHODS

Between Cable & Assembly:
Cable Flexing; MIL-C-24217 (4.7.5)
Between Contacts & Wire:

SPECIAL DESIGN FEATURES

Field Installable

SPECIAL OPTIONS

Right angle plug, pressure proof caps, hermetic feedthru receptacle

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

MANUFACTURER:

Burton Electrical Engineering

SERIES:

5800: Hermetic Feedthru

CATALOGUE
PAGE **iv**

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **MS**

STANDARD MATERIALS

Shell	S.S.
Boot/Jacket	Neoprene or Silicone Steel
Contacts & Plating	Copper - Gold
Insulator	Silicone Rubber
Coupling Ring/Nut	Bronze or S.S.

CONNECTOR SIZE

Max. Length (Assembled)	2.923"
Maximum Diameter*	2.087"

CONTACTS

Termination (Cable to Contact)	Crimp
Size Range	22, 20, 16, 12, 8, 4, 0
Number Range	1-35

SEALING DESIGNS

Plug to Receptacle	0-ring
Cable to Plug	Sleeve or molding
Contact Seal	0-ring
Receptacle to Bulkhead	0-ring

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	3-400 amps
Working Voltage	500 V
Withstanding Voltage	2000 V
Contact Resistance	2 milliohms

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	Environmental charac. follow MIL-STD-202
Mated	8,700 psi
Unmated	8,700 psi (recep)
Temperature Range	-50°C to 100°C
Durability:	
Number of Cycles	300
Expected Life	3 yr
Vibration	20-5000 Hz at 20 g
Physical Shock	11 ms at 150 g
Corrosion	6 cycles salt spray

* Including Hex Nut or Coupling Ring

POLARIZING METHOD

Keys; alternate keying available

STRAIN RELIEF METHODS

Between Cable & Assembly:
Cable to connector armor or molding and potting
Between Contacts & Wire:
Potting

SPECIAL DESIGN FEATURES

Shielding device; removable contact inserts; towing connector with electrical and mechanical connection

SPECIAL OPTIONS

Underwater snatch connector for connection between surface and undersea vessels; hermetic seals

RECOMMENDED ZONES OF APPLICATION

General Undersea

APPROXIMATE PRICE RANGE

\$50.00 to \$200.00

MANUFACTURER:

Compagnie Deutsch, France

SERIES:

DCI: Subminiatures and Submarines

CATALOGUE
PAGE

V

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION

MS

STANDARD MATERIALS

Shell	6061 - T6 Aluminum Alloy
Boot/Jacket	PVC Tubing
Contacts & Plating	Terillium Copper - Gold
Insulator	
Coupling Ring/Nut	6061 - T6 Alluminum Alloy

CONNECTOR SIZE

Max. Length (Assembled)	8.25"
Maximum Diameter*	3.75"

POLARIZING METHOD

Key

CONTACTS

Termination (Cable to Contact)	Pins
Size Range	
Number Range	130 Coaxials

STRAIN RELIEF METHODS

Between Cable & Assembly:

Between Contacts & Wire:

SEALING DESIGNS

Plug to Receptacle	O-ring
Cable to Plug	PVC Tubing
Contact Seal	
Receptacle to Bulkhead	

SPECIAL DESIGN FEATURES

2 accompanying patch boards with 260 pin terminated sockets each; longitudinal load capability of 4000 lb.

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	5 amps
Working Voltage	500 V (rms)
Withstanding Voltage	
Contact Resistance	0.72 milliohms

SPECIAL OPTIONS

See catalogue for additional special cable assemblies

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	Approx 750 psi
Unmated	
Temperature Range	
Durability:	
Number of Cycles	
Expected Life	
Vibration	
Physical Shock	
Corrosion	

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

MANUFACTURER:

ExCon, Inc.

SERIES:

ExCon 180-HD Quick Disconnect

* Including Hex Nut or Coupling Ring

CATALOGUE
PAGE

v

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **MS**

STANDARD MATERIALS

Shell	Aluminum Alloy Hard Anodized
Boot/Jacket	Molded Neoprene
Contacts & Plating	Copper Alloy - Gold
Insulator	Glass Epoxy
Coupling Ring/Nut	Aluminum Alloy Hard Anodized

CONNECTOR SIZE

Max. Length (Assembled)	2.5"
Maximum Diameter*	1.875"

CONTACTS

Termination (Cable to Contact)	Solder; Crimp
Size Range	22, 20, 16
Number Range	4-100

SEALING DESIGNS

Plug to Receptacle	O-ring
Cable to Plug	Molded Neoprene
Contact Seal	Potting
Receptacle to Bulkhead	O-ring

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	3 to 7.5 amps
Working Voltage	600 V dc
Withstanding Voltage	1000 V dc
Contact Resistance	50 milliohms

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	5000 psi
Unmated	0
Temperature Range	-67°F to 350°F
Durability:	
Number of Cycles	250
Expected Life	
Vibration	
Physical Shock	
Corrosion	96 hr. Salt Spray 5%

POLARIZING METHOD

Keys; alternate keying available

STRAIN RELIEF METHODS

Between Cable & Assembly:
Molded Neoprene

Between Contacts & Wire:

SPECIAL DESIGN FEATURES

Shielded crimp removable contacts;
replaceable O-rings

SPECIAL OPTIONS

Materials and compounds for
cable and cable molding are buna,
polyurethane, PVC, etc.

RECOMMENDED ZONES OF APPLICATION

Power and instrumentation, electrical
connectors for severe underwater
conditions.

APPROXIMATE PRICE RANGE

\$150.00 to \$180.00 sm. lots

MANUFACTURER:

Glenair, Inc.

SERIES:

GL 41, GL 43 - High Density

* Including Hex Nut or Coupling Ring

CATALOGUE
PAGE **v**

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **MS**

STANDARD MATERIALS

Shell	S.S.
Boot/Jacket	Molded Neoprene
Contacts & Plating	(P)Copper Alloy - Gold; (R) Alloy 52 - Gold
Insulator	(P)Glass Epoxy; (R) Glass Hermetic
Coupling Ring/Nut	Ring: Ni-Al-Bro; Jam Nut: S.S.

CONNECTOR SIZE

Max. Length (Assembled)	2.5"
Maximum Diameter*	1.875"

CONTACTS

Termination (Cable to Contact)	Solder
Size Range	22,20,16
Number Range	4-100

SEALING DESIGNS

Plug to Receptacle	2 O-rings
Cable to Plug	Molded Neoprene
Contact Seal	Potting and Glass
Receptacle to Bulkhead	O-ring

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	3 to 10 amps
Working Voltage	600 V dc
Withstanding Voltage	2300 V dc
Contact Resistance	50 milliohms

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	5000 psi
Unmated	(R-herm.) 5000 psi
Temperature Range	-67°F to 350°F
Durability:	
Number of Cycles	250
Expected Life	10 yr
Vibration	
Physical Shock	50 g
Corrosion	60-day immersion

POLARIZING METHOD

Keys; alternate keying available

STRAIN RELIEF METHODS

Between Cable & Assembly:
Molded Neoprene

Between Contacts & Wire:

SPECIAL DESIGN FEATURES

High density contact arrangements, 4 shell sizes; cable plug and receptacle, front mount receptacle, rear mount receptacle

SPECIAL OPTIONS

Body configurations to customer requirements; nonhermetic receptacles for less severe requirements.

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

Approx. \$200.00 sm. lots

MANUFACTURER:

Glenair, Inc.

SERIES:

GL4000 - High Density

*Including Hex Nut or Coupling Ring

CATALOGUE
PAGE **v**

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **MS**

STANDARD MATERIALS

Shell	316 S.S. Passivated
Boot/Jacket	Polyurethane, Neoprene or other
Contacts & Plating	(P) Copper Alloy - Gold; (R) Mild Steel - Gold
Insulator	(P) Diallyl Phthalate; (R) Compression Glass
Coupling Ring/Nut	Bronze

CONNECTOR SIZE

Max. Length (Assembled)	Approx. 6"
Maximum Diameter*	4.625"

CONTACTS

Termination (Cable to Contact)	Plugs/Receptacles
Size Range	22, 16, 12, 8, 4, 0
Number Range	3-48

SEALING DESIGNS

Plug to Receptacle	2 O-rings
Cable to Plug	Molding
Contact Seal	Compression Glass
Receptacle to Bulkhead	2 O-rings; weld

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	10 to 100 amps
Working Voltage	625 V ac
Withstanding Voltage	(Dielectric): 1800 V ac
Contact Resistance	4.5 (#16) milliohms

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	10,000 psi
Unmated	(R) 10,000 psi
Temperature Range	-65°F to 165°F
Durability:	
Number of Cycles	
Expected Life	50 yr
Vibration	MIL-STD-202 (204-A)
Physical Shock	MIL-STD-202 (207)
Corrosion	Inherently High

POLARIZING METHOD

2 Keys: alternate keying available

STRAIN RELIEF METHODS

Between Cable & Assembly:
Molding

Between Contacts & Wire:
molding or cast epoxy
prepotting and shrink sleeves

SPECIAL DESIGN FEATURES

Removable plug contact inserts

SPECIAL OPTIONS

RECOMMENDED ZONES OF APPLICATION

High pressure, including submarines, offshore well applications.

APPROXIMATE PRICE RANGE

MANUFACTURER:

ITT Cannon Electric, Phoenix

SERIES:

MIL-C-24217

* Including Hex Nut or Coupling Ring

CATALOGUE
PAGE **vi**

PRODUCT MATRIX

CONNECTOR CLASSIFICATION **MS**

STANDARD MATERIALS

Shell	316 S.S.
Boot/Jacket	Polyurethane, Neoprene or other
Contacts & Plating	(P) Copper Alloy - Gold; (R) Molybdenum - Gold
Insulator	(P) Diallyl Phthalate; (R) Compression Glass
Coupling Ring/Nut	Bronze

CONNECTOR SIZE

Max. Length (Assembled)	Approx. 12"
Maximum Diameter*	11.75"

POLARIZING METHOD

2 Keys

CONTACTS

Termination (Cable to Contact)	Solder, Crimp, Taper pin
Size Range	22, 20, 16, 12, 4
Number Range	3-208

STRAIN RELIEF METHODS

Between Cable & Assembly:
Optional cable clamps
Kellems Grip; molding
Between Contacts & Wire:
Shrink sleeve on terminations
Potting or molding

SEALING DESIGNS

Plug to Receptacle	2 O-rings
Cable to Plug	Potting and/or Molding
Contact Seal	Compression Glass
Receptacle to Bulkhead	2 O-rings

SPECIAL DESIGN FEATURES

Feed thru with mating plugs on each end

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	5 to 110 amps
Working Voltage	440 V ac
Withstanding Voltage	600 V ac
Contact Resistance	0.4 to 8 milliohms

SPECIAL OPTIONS

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	MIL-C-22249
Unmated	MIL-C-22249
Temperature Range	-65°F to 160°F
Durability:	
Number of Cycles	200 Estim. Min.
Expected Life	40 yr
Vibration	MIL-STD-167 (I)
Physical Shock	MIL-S-901 (B,2)
Corrosion	Inherently High

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

MANUFACTURER:

ITT Cannon Electric, Phoenix

SERIES:

MIL-C-22249

* Including Hex Nut or Coupling Ring

CATALOGUE PAGE **vi**

PRODUCT MATRIX

CONNECTOR CLASSIFICATION **MS**

STANDARD MATERIALS

Shell	S.S., Passivated
Boot/Jacket	Polyurethane, Neoprene or other
Contacts & Plating	(P) Copper Alloy - Gold; (R) Molybdenum
Insulator	(P) Diallyl Phthalate; (R) Compression Glass
Coupling Ring/Nut	Bronze

CONNECTOR SIZE

Max. Length (Assembled)	
Maximum Diameter*	11.750"

CONTACTS

Termination (Cable to Contact)	Crimp
Size Range	20, 16, 10, 4, 0
Number Range	3-208

SEALING DESIGNS

Plug to Receptacle	O-ring
Cable to Plug	Molding
Contact Seal	Grommet
Receptacle to Bulkhead	O-ring

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	5 to 110
Working Voltage	
Withstanding Voltage	MIL-STD-202 (301)
Contact Resistance	

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	10,000 psi
Unmated	10,000 psi
Temperature Range	
Durability:	
Number of Cycles	
Expected Life	
Vibration	MIL-STD-167 (I)
Physical Shock	MIL-S-901 (B-2)
Corrosion	

POLARIZING METHOD

2 Keys

STRAIN RELIEF METHODS

Between Cable & Assembly:
Molding; Cable Clamp
Between Contacts & Wire:

SPECIAL DESIGN FEATURES

Rear release contact retention assy.; Feed thru pin-pin contacts

SPECIAL OPTIONS

Right angle plug

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

MANUFACTURER:

ITT Cannon Electric, Phoenix

SERIES:

MIL-C-22539

* Including Hex Nut or Coupling Ring

CATALOGUE PAGE **vi**

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **MS**

STANDARD MATERIALS

Shell	Brass-Nickel Plate
Boot/Jacket	
Contacts & Plating	Copper Alloy, Silver Plate
Insulator	Melamine
Coupling Ring/Nut	

CONNECTOR SIZE

Max. Length (Assembled)	
Maximum Diameter*	1.625" to 4.250"

CONTACTS

Termination (Cable to Contact)	Solder pot
Size Range	16, 12, 8, 4, 0
Number Range	1-56

SEALING DESIGNS

Plug to Receptacle	O-ring
Cable to Plug	Compressible bushing
Contact Seal	
Receptacle to Bulkhead	

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	22 to 245 amps
Working Voltage	various
Withstanding Voltage	1000 to 7000 V (rms)
Contact Resistance	

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	4,500 psi
Unmated	
Temperature Range	-55°C to 85°C
Durability:	
Number of Cycles	
Expected Life	
Vibration	
Physical Shock	
Corrosion	

POLARIZING METHOD

Key

STRAIN RELIEF METHODS

Between Cable & Assembly:
Optional Kellems grips;
cable clamps
Between Contacts & Wire:

SPECIAL DESIGN FEATURES

Acme threads for coupling

SPECIAL OPTIONS

Cable clamps, Kellems grips,
caps -- plug and receptacle

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

MANUFACTURER:

ITT Cannon Electric, Ontario

SERIES:

W: plug; Receptacle; wall
mounting

* Including Hex Nut or Coupling Ring

CATALOGUE
PAGE **vi**

PRODUCT MATRIX

CONNECTOR CLASSIFICATION **MS**

STANDARD MATERIALS

Shell	S.S.
Boot/Jacket	
Contacts & Plating	S.S. or Silver Plated Brass
Insulator	
Coupling Ring/Nut	

CONNECTOR SIZE

Max. Length (Assembled)	
Maximum Diameter*	5/16"

POLARIZING METHOD

CONTACTS

Termination (Cable to Contact)	
Size Range	18, 16
Number Range	1

STRAIN RELIEF METHODS

Between Cable & Assembly:

Between Contacts & Wire:

SEALING DESIGNS

Plug to Receptacle	Interference
Cable to Plug	Molded
Contact Seal	
Receptacle to Bulkhead	

SPECIAL DESIGN FEATURES

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	7 to 10 amps
Working Voltage	600 V
Withstanding Voltage	
Contact Resistance	

SPECIAL OPTIONS

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	20,000 psi
Unmated	
Temperature Range	
Durability:	
Number of Cycles	
Expected Life	
Vibration	
Physical Shock	
Corrosion	

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

MANUFACTURER:

Joy Manufacturing Co.

SERIES:

X8372

* Including Hex Nut or Coupling Ring

CATALOGUE PAGE **vi**

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **MS**

STANDARD MATERIALS

Shell	(R) 416 S.S.; (P) Neoprene
Boot/Jacket	Neoprene
Contacts & Plating	Beryllium Copper - Silver
Insulator	(R) Hi-temp Epoxy; (P) Glass Laminate
Coupling Ring/Nut	

CONNECTOR SIZE

Max. Length (Assembled)	Approx. 3"
Maximum Diameter*	

CONTACTS

Termination (Cable to Contact)	Pins
Size Range	
Number Range	2-6

SEALING DESIGNS

Plug to Receptacle	Interference
Cable to Plug	Neoprene Mold
Contact Seal	Epoxy
Receptacle to Bulkhead	O-ring

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	15 amps
Working Voltage	1000 to 3000 V
Withstanding Voltage	
Contact Resistance	

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	20,000 psi
Unmated	
Temperature Range	max 300°F
Durability:	
Number of Cycles	
Expected Life	
Vibration	
Physical Shock	
Corrosion	

POLARIZING METHOD

STRAIN RELIEF METHODS

Between Cable & Assembly:
Molded Neoprene
Between Contacts & Wire:

SPECIAL DESIGN FEATURES

SPECIAL OPTIONS

See catalogue for additional right angles, multiple feedthrus, ceramic and glass sealed connectors

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

MANUFACTURER:

Kemlon Products, Inc.

SERIES:

K, MS Multiple Contact

*Including Hex Nut or Coupling Ring

CATALOGUE
PAGE **vi**

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **MS**

STANDARD MATERIALS

Shell	(R) 416 S.S.; (P) Neoprene
Boot/Jacket	Neoprene
Contacts & Plating	Beryllium Copper - Silver
Insulator	(R) Hi-temp Epoxy; (P) Teflon or Neoprene
Coupling Ring/Nut	416 S.S.

CONNECTOR SIZE

Max. Length (Assembled)	Approx. 6"
Maximum Diameter*	1/2"

CONTACTS

Termination (Cable to Contact)	Pin
Size Range	
Number Range	1

SEALING DESIGNS

Plug to Receptacle	Interference
Cable to Plug	Neoprene Mold
Contact Seal	Epoxy
Receptacle to Bulkhead	O-ring

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	15 amps
Working Voltage	500 to 3000 V
Withstanding Voltage	
Contact Resistance	

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	20,000 psi
Unmated	
Temperature Range	Max. 300°F
Durability:	
Number of Cycles	
Expected Life	
Vibration	
Physical Shock	
Corrosion	

POLARIZING METHOD

STRAIN RELIEF METHODS

Between Cable & Assembly:
Molded Neoprene
Between Contacts & Wire:

SPECIAL DESIGN FEATURES

SPECIAL OPTIONS

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

MANUFACTURER:

Kemlon Products, Inc.

SERIES:

K, MS Single Contact

* Including Hex Nut or Coupling Ring

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **MS**

STANDARD MATERIALS

Shell	316 S.S.; Anodized Al; Navy Brass (special)
Boot/Jacket	Neoprene Molding Compound
Contacts & Plating	Brass -- Gold or Silver
Insulator	Kintec, Inc. K-500
Coupling Ring/Nut	Anodized Al, Ni-Al-Brass

CONNECTOR SIZE

Max. Length (Assembled)	6.8" to 12.0"
Maximum Diameter*	1.38" to 4.38"

CONTACTS

Termination (Cable to Contact)	Solder
Size Range	20, 16, 14, 10, 8, 0 Coax
Number Range	1 - 82; Coax

SEALING DESIGNS

Plug to Receptacle	Redundant O-ring
Cable to Plug	Neopr., Plyuret., Mold
Contact Seal	Molding
Receptacle to Bulkhead	O-ring

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	0 to 600 amps
Working Voltage	to 18,000 V
Withstanding Voltage	2 x wkg. vltg. + 1000
Contact Resistance	.5 to .25 milliohms

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	20,000 psi
Unmated	10,000 psi
Temperature Range	to 450°F
Durability:	
Number of Cycles	
Expected Life	to 20 yr
Vibration	as required
Physical Shock	as required
Corrosion	as required

POLARIZING METHOD

Key; alternate keying positions available

STRAIN RELIEF METHODS

Between Cable & Assembly:

Hard Encapsulation

Between Contacts & Wire:

Hard Encapsulation

SPECIAL DESIGN FEATURES

Field-installable assy.; shielding device; removable contact inserts; flanged bulkhead receptacle; right angle mold

SPECIAL OPTIONS

Pressure-balanced oil-filled assembly; high voltage insert; multi-wire termination, protective cap

RECOMMENDED ZONES OF APPLICATION

Down-hole logging; deep ocean applications

APPROXIMATE PRICE RANGE

\$400 to \$1500.00

MANUFACTURER:

Kintec, Inc.

SERIES:

LP

* Including Hex Nut or Coupling Ring

CATALOGUE
PAGE **vi**

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **MS**

STANDARD MATERIALS

Shell	316 S.S.
Boot/Jacket	Neoprene Molding Compound
Contacts & Plating	Brass - Gold
Insulator	Kintec, Inc. K-500
Coupling Ring/Nut	Ni-Al-Brass

CONNECTOR SIZE

Max. Length (Assembled)	6.5" to 8.2"
Maximum Diameter*	1.58" to 2.75"

CONTACTS

Termination (Cable to Contact)	Solder
Size Range	20, 16, 14, 8, 4, 0
Number Range	1-33

SEALING DESIGNS

Plug to Receptacle	Redundant O-ring
Cable to Plug	Neopre.Plyuret. Mold
Contact Seal	Molding
Receptacle to Bulkhead	O-ring

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	0 to 600 amps
Working Voltage	to 18,000 V
Withstanding Voltage	2 x wkg. vltg. + 1000
Contact Resistance	.5 - .25 milliohms

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	20,000 psi
Unmated	10,000 psi
Temperature Range	to 450°F
Durability:	
Number of Cycles	
Expected Life	to 20 yr
Vibration	as required
Physical Shock	as required
Corrosion	as required

POLARIZING METHOD

Keys

STRAIN RELIEF METHODS

Between Cable & Assembly:
Hard Encapsulation
Between Contacts & Wire:
Hard Encapsulation

SPECIAL DESIGN FEATURES

Shielding device, removable contact inserts; field-inst. assy.; flanged bulkhead receptacle; right angle plug

SPECIAL OPTIONS

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

MANUFACTURER:

Kintec, Inc.

SERIES:

MS09, MS14, MS24 -- MIL-C-24217 interface

* Including Hex Nut or Coupling Ring

CATALOGUE
PAGE **vi**

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **MS**

STANDARD MATERIALS

Shell	(P) 316 S.S.; (R) 316L S.S.
Boot/Jacket	Various
Contacts & Plating	(P) Copper Alloy - Gold; (R) Steel - Gold
Insulator	(P) Diallyl Phthalate; (R) Compression Glass
Coupling Ring/Nut	Ni-Al-Bronze

CONNECTOR SIZE

Max. Length (Assembled)	
Maximum Diameter*	1.626" to 5.500"

CONTACTS

Termination (Cable to Contact)	Solder
Size Range	16, 12, Coax
Number Range	3-68

SEALING DESIGNS

Plug to Receptacle	2 O-rings
Cable to Plug	
Contact Seal	Glass
Receptacle to Bulkhead	Weld, Flange Bolt

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	
Working Voltage	
Withstanding Voltage	1,000 V (rms)
Contact Resistance	55-70 mV drop

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	2000 psig
Unmated	
Temperature Range	
Durability:	
Number of Cycles	
Expected Life	
Vibration	
Physical Shock	
Corrosion	

POLARIZING METHOD

Key; alternate keying positions available

STRAIN RELIEF METHODS

Between Cable & Assembly:

Between Contacts & Wire:

SPECIAL DESIGN FEATURES

Available Mountings:
Weld, Flanged Splice;
End Flange Bolted

SPECIAL OPTIONS

Pressure proof caps

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

MANUFACTURER:

D.G. O'Brien, Inc.

SERIES:

101: MIL-C-22539

* Including Hex Nut or Coupling Ring

CATALOGUE
PAGE **vi**

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **MS**

STANDARD MATERIALS

Shell	(P) 316 S.S.; (R) 316L S.S
Boot/Jacket	Various
Contacts & Plating	(P) Copper Alloy - Gold; (R) Steel-Gold
Insulator	(P) Diallyl Phthalate; (R) Compression Glass
Coupling Ring/Nut	Ni-Al-Bronze

CONNECTOR SIZE

Max. Length (Assembled)	
Maximum Diameter*	1.125" to 2.510"

CONTACTS

Termination (Cable to Contact)	Crimp
Size Range	16, Coax
Number Range	5-8

SEALING DESIGNS

Plug to Receptacle	2 O-rings
Cable to Plug	
Contact Seal	Glass
Receptacle to Bulkhead	

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	
Working Voltage	
Withstanding Voltage	1000 V (rms)
Contact Resistance	40 mV drop

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	2000 psig
Unmated	
Temperature Range	
Durability:	
Number of Cycles	
Expected Life	
Vibration	
Physical Shock	
Corrosion	

POLARIZING METHOD

Key; alternate keying positions available

STRAIN RELIEF METHODS

Between Cable & Assembly:

Between Contacts & Wire:

SPECIAL DESIGN FEATURES

Right angle plugs available; receptacles in weld, lock-nut flange, flange bolted and AN port mountings

SPECIAL OPTIONS

(P) Insulator available in Delrin L-P-392; pressure proof caps

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

MANUFACTURER:

D.G. O'Brien, Inc.

SERIES:

101, 104

* Including Hex Nut or Coupling Ring

CATALOGUE
PAGE **vi**

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **MS**

STANDARD MATERIALS

Shell	(P) 316 S.S.; (R) 316L S.S.
Boot/Jacket	Various
Contacts & Plating	(P) Copper Alloy - Gold; (R) Steel - Gold
Insulator	(P) Diallyl Phthalate or Delrin; (R) Compression Glass
Coupling Ring/Nut	Ni-Al-Bronze

CONNECTOR SIZE

Max. Length (Assembled)	
Maximum Diameter*	1.061" to 5.500"

CONTACTS

Termination (Cable to Contact)	Crimp Socket
Size Range	16, 12, 8, 4, 0
Number Range	Coax-48

SEALING DESIGNS

Plug to Receptacle	
Cable to Plug	
Contact Seal	
Receptacle to Bulkhead	2 O-rings

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	
Working Voltage	
Withstanding Voltage	1900 V (rms)
Contact Resistance	55 mV drop

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	10,000 psig
Unmated	
Temperature Range	-65°F to 165°F
Durability:	
Number of Cycles	
Expected Life	
Vibration	10-2000 Hz at 10 g
Physical Shock	MIL-STD-202(207)
Corrosion	

POLARIZING METHOD

Key; alternate keying positions available

STRAIN RELIEF METHODS

Between Cable & Assembly:

Between Contacts & Wire:

SPECIAL DESIGN FEATURES

Various mountings available - see catalogue

SPECIAL OPTIONS

Right angle plugs; pressure proof caps

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

MANUFACTURER:

D.G. O'Brien, Inc.

SERIES:

107: MIL-C-24217

* Including Hex Nut or Coupling Ring

CATALOGUE
PAGE **vi**

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **MS**

STANDARD MATERIALS

Shell	316 S.S.
Boot/Jacket	Various
Contacts & Plating	(P) Copper Alloy - Gold; (R) Steel - Gold
Insulator	(P) Nylon; (R) Compression Glass
Coupling Ring/Nut	316 S.S.

CONNECTOR SIZE

Max. Length (Assembled)	
Maximum Diameter*	0.750"

CONTACTS

Termination (Cable to Contact)	
Size Range	22, 16, RG58C/U
Number Range	1-2

SEALING DESIGNS

Plug to Receptacle	0-ring
Cable to Plug	
Contact Seal	
Receptacle to Bulkhead	0-ring

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	
Working Voltage	
Withstanding Voltage	
Contact Resistance	

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	10,000 psig
Unmated	
Temperature Range	-67°F to 185°F
Durability:	
Number of Cycles	
Expected Life	
Vibration	
Physical Shock	
Corrosion	

POLARIZING METHOD

STRAIN RELIEF METHODS

Between Cable & Assembly:

Between Contacts & Wire:

SPECIAL DESIGN FEATURES

SPECIAL OPTIONS

Pressure proof caps

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

MANUFACTURER:

D.G. O'Brien, Inc.

SERIES:

110 - Coaxial

* Including Hex Nut or Coupling Ring

CATALOGUE
PAGE **vi**

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **MS**

STANDARD MATERIALS

Shell	(P) 316 S.S.; (R) 316L S.S.
Boot/Jacket	Various
Contacts & Plating	(P) Copper Alloy - Gold; (R) Steel - Gold
Insulator	(P) Glass Epoxy; (R) Glass
Coupling Ring/Nut	Ni-Al-Bronze

CONNECTOR SIZE

Max. Length (Assembled)	
Maximum Diameter*	0.625" to 1.062"

CONTACTS

Termination (Cable to Contact)	Crimp Socket
Size Range	24, 20
Number Range	5-12

SEALING DESIGNS

Plug to Receptacle	
Cable to Plug	
Contact Seal	
Receptacle to Bulkhead	O-ring

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	5 amps
Working Voltage	
Withstanding Voltage	625 V (rms)
Contact Resistance	

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	1000 psig
Unmated	
Temperature Range	-65°F to 160°F
Durability:	
Number of Cycles	
Expected Life	
Vibration	
Physical Shock	
Corrosion	

POLARIZING METHOD

Key: alternate keying positions available

STRAIN RELIEF METHODS

Between Cable & Assembly:

Between Contacts & Wire:

SPECIAL DESIGN FEATURES

Several receptacle mountings available

SPECIAL OPTIONS

Pressure proof caps

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

MANUFACTURER:

D.G. O'Brien, Inc.

SERIES:

124

* Including Hex Nut or Coupling Ring

CATALOGUE
PAGE **vi**

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **MS**

STANDARD MATERIALS

Shell	316L S.S.
Boot/Jacket	Various
Contacts & Plating	(P) Steel - Copper Alloy - Gold; (R) Steel - Gold
Insulator	(P) Delrin per L-P-392 and Glass; (R) Glass
Coupling Ring/Nut	Ni-Al-Bronze

CONNECTOR SIZE

Max. Length (Assembled)	
Maximum Diameter*	1.500" to 7.010"

CONTACTS

Termination (Cable to Contact)	
Size Range	16, 4
Number Range	Coax-48

SEALING DESIGNS

Plug to Receptacle	0-ring
Cable to Plug	
Contact Seal	Glass
Receptacle to Bulkhead	2 0-rings

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	
Working Voltage	
Withstanding Voltage	1500 V (rms)
Contact Resistance	110 mV drop

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	15,000 psig
Unmated	
Temperature Range	-67°F to 185°F
Durability:	
Number of Cycles	
Expected Life	
Vibration	MIL-STD-202 (204)
Physical Shock	MIL-STD-202 (207)
Corrosion	

POLARIZING METHOD

Key; alternate keying positions available

STRAIN RELIEF METHODS

Between Cable & Assembly:

Between Contacts & Wire:

SPECIAL DESIGN FEATURES

Right angle plug available; termination with oil-filled or convent. cables.

SPECIAL OPTIONS

Pressure proof caps

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

MANUFACTURER:

D.G. O'Brien, Inc.

SERIES:

126

* Including Hex Nut or Coupling Ring

PRODUCT MATRIX

CONNECTOR CLASSIFICATION **MS**

STANDARD MATERIALS

Shell	316L S.S. Passivated or Ni-Al-Bronze
Boot/Jacket	Neoprene
Contacts & Plating	Copper Alloy - Gold
Insulator	Molded Neoprene
Coupling Ring/Nut	Ni-Al-Bronze

CONNECTOR SIZE

Max. Length (Assembled)	8.75" (size 4)
Maximum Diameter*	1.713" (size 4)

CONTACTS

Termination (Cable to Contact)	
Size Range	20, 16, 8, 2
Number Range	4-68

SEALING DESIGNS

Plug to Receptacle	
Cable to Plug	Gland, O-ring, & Boot
Contact Seal	Molding
Receptacle to Bulkhead	O-ring

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	7.5 to 400 amps
Working Voltage	500 V (rms)
Withstanding Voltage	2,500 V (rms)
Contact Resistance	10 milliohms

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	5000 psi
Unmated	5000 psi
Temperature Range	-20°F to 160°F
Durability:	
Number of Cycles	200
Expected Life	
Vibration	
Physical Shock	
Corrosion	

POLARIZING METHOD

Keys; alternate keying positions available

STRAIN RELIEF METHODS

Between Cable & Assembly:
2 half clamps in end bell
Between Contacts & Wire:

SPECIAL DESIGN FEATURES

Shielding Device

SPECIAL OPTIONS

Special layout; shell materials; automatic disconnection; high working voltage

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

\$140.00 to \$280.00

MANUFACTURER:

Souriau & Cie. (Dist. Interocean Systems, Inc., San Diego)

SERIES:

8810; see catalogue for Series 8804, 8805

* Including Hex Nut or Coupling Ring

CATALOGUE PAGE **vii**

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **MS**

STANDARD MATERIALS

Shell	S.S. Type 316
Boot/Jacket	Various, depending on cable
Contacts & Plating	Brass - Gold
Insulator	Glass Epcxy
Coupling Ring/Nut	Ni-Al-Bronze

CONNECTOR SIZE

Max. Length (Assembled)	Approx. 11"
Maximum Diameter*	3.875"

CONTACTS

Termination (Cable to Contact)	Solder
Size Range	16, 14, 10, 8, 6, 4, 0
Number Range	1-75

SEALING DESIGNS

Plug to Receptacle	2 O-rings
Cable to Plug	Potting and Bond
Contact Seal	Hermetic Bond
Receptacle to Bulkhead	2 O-rings

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	5 to 200 amps
Working Voltage	600 V
Withstanding Voltage	1500 V
Contact Resistance	Various

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	15,000 psi
Unmated	5,000 psi
Temperature Range	Up to 250°F
Durability:	
Number of Cycles	
Expected Life	
Vibration	MIL-C-24217
Physical Shock	MIL-C-24217
Corrosion	MIL-C-24217

* Including Hex Nut or Coupling Ring

POLARIZING METHOD

Keys; alternate keying positions available

STRAIN RELIEF METHODS

Between Cable & Assembly:
Molded taper junctions, springs compatible with cable jackets
Between Contacts & Wire:
Back shell fill

SPECIAL DESIGN FEATURES

Locking sleeve; shielding device; removable contact inserts; metal to metal faying of receptacle to blkhd to prevent face O-ring extrusion

SPECIAL OPTIONS

Many other materials on special order; wire by wire integrity through filling conductor strands and completely waterblocking cable to connector junction

RECOMMENDED ZONES OF APPLICATION

High stress undersea environments

APPROXIMATE PRICE RANGE

Variable

MANUFACTURER:

Vector Cable Co.

SERIES:

MS (2)

CATALOGUE
PAGE **vii**

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **MS**

STANDARD MATERIALS

Shell	ARMCO 22-13-5
Boot/Jacket	
Contacts & Plating	(P) Copper Alloy - Gold; (R) Steel - Gold
Insulator	(P) Diallyl Phthalate; (R) Compression Glass
Coupling Ring/Nut	Ni-Al-Bronze

CONNECTOR SIZE

Max. Length (Assembled)	3.0"
Maximum Diameter*	1.4"

CONTACTS

Termination (Cable to Contact)	Solder; Crimp
Size Range	20, 16, 12
Number Range	3-19

SEALING DESIGNS

Plug to Receptacle	O-ring
Cable to Plug	Molded
Contact Seal	(R) Glass Hermetic
Receptacle to Bulkhead	O-ring

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	30 to 70 amps
Working Voltage	625 V ac (rms)
Withstanding Voltage	1000 or 1872 V ac
Contact Resistance	

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	10,000 psi
Unmated	(R) 10,000 psi
Temperature Range	-54°C to 73°C
Durability:	
Number of Cycles	100
Expected Life	
Vibration	
Physical Shock	
Corrosion	

POLARIZING METHOD

Keys; alternate keying positions available

STRAIN RELIEF METHODS

Between Cable & Assembly:

Molding

Between Contacts & Wire:

Heat shrink tubing or molding

SPECIAL DESIGN FEATURES

Removable contact plug inserts

SPECIAL OPTIONS

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

\$200.00 to \$400.00

MANUFACTURER:

Viking Industries

SERIES:

13: MIL-C-24217 Miniature

* Including Hex Nut or Coupling Ring

CATALOGUE
PAGE

vii

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **MS**

STANDARD MATERIALS

Shell	(P) 316 S.S Passivated; (R) 316L S.S Passivated
Boot/Jacket	Various Molded
Contacts & Plating	(P) Copper Alloy - Gold; (R) Steel or Molybdenum - Gold
Insulator	(P) Diallyl Phthalate; (R) Compression Glass
Coupling Ring/Nut	Ni-Al-Bronze

CONNECTOR SIZE

Max. Length (Assembled)	7.5"
Maximum Diameter*	5.0"

CONTACTS

Termination (Cable to Contact)	Solder; Crimp
Size Range	16, 12, 8, 4, 0
Number Range	3-37

SEALING DESIGNS

Plug to Receptacle	O-ring
Cable to Plug	Molded
Contact Seal	(R) - glass hermetic
Receptacle to Bulkhead	O-ring

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	13 to 200 amps
Working Voltage	625 V ac (rms)
Withstanding Voltage	1000 or 1872 V ac
Contact Resistance	

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	10,000 psi
Unmated	(R) 10,000 psi
Temperature Range	-54°C to 73°C
Durability:	
Number of Cycles	100
Expected Life	
Vibration	MIL-STD-202(202-A)
Physical Shock	MIL-STD-202(207)
Corrosion	

POLARIZING METHOD

Keys; alternate keying positions available

STRAIN RELIEF METHODS

Between Cable & Assembly:
Molding

Between Contacts & Wire:
Heat shrink tubing or molding

SPECIAL DESIGN FEATURES

Removable contact plug inserts

SPECIAL OPTIONS

MIL-C-22249 and MIL-C-22539
Connectors available

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

\$200.00 to \$600.00

MANUFACTURER:

Viking Industries, Inc.

SERIES:

14: MIL-C-24217

* Including Hex Nut or Coupling Ring

CATALOGUE
PAGE **vii**

AD-A036 841

WASHINGTON UNIV SEATTLE APPLIED PHYSICS LAB
INTERFERENCE SEALS AND CONNECTORS FOR UNDERSEA ELECTRICAL APPLI--ETC(U)
JUL 76 J PARADIS

F/G 13/10

N00017-74-C-1208

NL

UNCLASSIFIED

3 OF 4
AD
A036841



1000

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **PBO**

STANDARD MATERIALS

Shell	S.S. or Glass Epoxy
Boot/Jacket	Neoprene or Polyurethane
Contacts & Plating	Brass, Bronze, Copper Alloy, Gold Plating, MIL-645204 - Type 2 Class 2
Insulator	Glass Epoxy
Coupling Ring/Nut	Nylon, S.S. or Ni-Al-Bronze

CONNECTOR SIZE

Max. Length (Assembled)	4" to 23"
Maximum Diameter*	3.87"

CONTACTS

Termination (Cable to Contact)	Solder
Size Range	20, 16, 14, 10, 8, 6, 4, 0
Number Range	1 to 85

SEALING DESIGNS

Plug to Receptacle	O-ring
Cable to Plug	Band or Ties
Contact Seal	Glass Epoxy
Receptacle to Bulkhead	O-ring

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	3 to 200 amps
Working Voltage	300-600 V dc
Withstanding Voltage	1500 V dc
Contact Resistance	Various

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	13,500 psi
Unmated	13,500 psi
Temperature Range	20°F to 200°F
Durability:	
Number of Cycles	
Expected Life	1-20 yr
Vibration	
Physical Shock	
Corrosion	

POLARIZING METHOD

Pins: keys

STRAIN RELIEF METHODS

Between Cable & Assembly:

Between Contacts & Wire:

Slack in Conductors

SPECIAL DESIGN FEATURES

Locking sleeve; shielding device; removable contact inserts; pressure balanced

SPECIAL OPTIONS

Right angles; flange mounts; dummies; field installable

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

\$85.00 to \$1200.00

MANUFACTURER:

Brantner/Rochester

SERIES:

XSL, XSQ, MSS, MNM, etc.
Pressure-Balanced Oil-Filled

* Including Hex Nut or Coupling Ring

CATALOGUE
PAGE **iv**

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **PBOF**

STANDARD MATERIALS

Shell
Boot/Jacket
Contacts & Plating
Insulator
Coupling Ring/Nut

For Standard Characteristics See Kintec MS Connectors --
Series LP

CONNECTOR SIZE

Max. Length (Assembled)
Maximum Diameter*

POLARIZING METHOD

CONTACTS

Termination (Cable to
Contact)
Size Range
Number Range

STRAIN RELIEF METHODS

Between Cable & Assembly:

Between Contacts & Wire:

SEALING DESIGNS

Plug to Receptacle
Cable to Plug
Contact Seal
Receptacle to Bulkhead

SPECIAL DESIGN FEATURES

ELECTRICAL CHARACTERISTICS

Max. Current Capacity
Working Voltage
Withstanding Voltage
Contact Resistance

SPECIAL OPTIONS

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure
Range:
 Mated
 Unmated
Temperature Range
Durability:
 Number of Cycles
 Expected Life
Vibration
Physical Shock
Corrosion

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

MANUFACTURER:

Kintec, Inc.

SERIES:

LP — Pressure-Balanced Oil-Filled

* Including Hex Nut or Coupling Ring

CATALOGUE
PAGE **vi**

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **PBOF**

STANDARD MATERIALS

Shell
Boot/Jacket
Contacts & Plating
Insulator
Coupling Ring/Nut

Various Adapters, Clamps, Tubing
Breakouts Available for Use with O'Brien C117, C126, C127
Connectors
----- See Catalogue

CONNECTOR SIZE

Max. Length (Assembled)
Maximum Diameter*

POLARIZING METHOD

CONTACTS

Termination (Cable to Contact)
Size Range
Number Range

STRAIN RELIEF METHODS

Between Cable & Assembly:

Between Contacts & Wire:

SEALING DESIGNS

Plug to Receptacle
Cable to Plug
Contact Seal
Receptacle to Bulkhead

SPECIAL DESIGN FEATURES

ELECTRICAL CHARACTERISTICS

Max. Current Capacity
Working Voltage
Withstanding Voltage
Contact Resistance

SPECIAL OPTIONS

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:
Mated
Unmated
Temperature Range
Durability:
Number of Cycles
Expected Life
Vibration
Physical Shock
Corrosion

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

MANUFACTURER:

D.G. O'Brien, Inc.

SERIES:

C40 Fluid-filled Cable Assemblies

* Including Hex Nut or Coupling Ring

CATALOGUE
PAGE **vi**

3C

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION

UM

STANDARD MATERIALS

Shell	
Boot/Jacket	Neoprene
Contacts & Plating	Beryllium Copper - Plating Optional
Insulator	
Coupling Ring/Nut	S.S. or Delrin

CONNECTOR SIZE

Max. Length (Assembled)	3-3/4"
Maximum Diameter*	3-1/2"

CONTACTS

Termination (Cable to Contact)	Solder
Size Range	20, 16, 12, 8, 4, 0, 0000
Number Range	1-8

SEALING DESIGNS

Plug to Receptacle	Interference
Cable to Plug	Injection Molding
Contact Seal	Interference
Receptacle to Bulkhead	O-ring

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	7-1/2 to 175 amps
Working Voltage	115 to 440 V dc
Withstanding Voltage	1200 V dc
Contact Resistance	5 milliohms

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	20,000 psi
Unmated	(P) 20,000; (R) 3,000
Temperature Range	-40°F to 165°F
Durability:	
Number of Cycles	500
Expected Life	3 yr
Vibration	
Physical Shock	
Corrosion	

POLARIZING METHOD

Pins; alternate pin arrangements available

STRAIN RELIEF METHODS

Between Cable & Assembly:

Taper

Between Contacts & Wire:

Service Loop on 51E, F

SPECIAL DESIGN FEATURES

"Watermate" underwater mateable connector; pressure balanced

SPECIAL OPTIONS

Various shell materials and designs, contact materials, formulation (e.g., silicon hypalon); wires can be combined in connectors using various sized contacts

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

\$18.00 to \$240.00

MANUFACTURER:

Electro

SERIES:

51 E, F, H, L

* Including Hex Nut or Coupling Ring

CATALOGUE
PAGE

v

PRODUCT MATRIX

CONNECTOR CLASSIFICATION **UM**

STANDARD MATERIALS

Shell	S.S.
Boot/Jacket	Neoprene
Contacts & Plating	Beryllium Copper - Plating Optional
Insulator	Various
Coupling Ring/Nut	S.S. or Delrin

CONNECTOR SIZE

Max. Length (Assembled)	2-7/16" to 6 1/4"
Maximum Diameter*	3-1/2"

CONTACTS

Termination (Cable to Contact)	Solder
Size Range	18, 16, 8, 4, 1
Number Range	1-8

SEALING DESIGNS

Plug to Receptacle	Interference
Cable to Plug	Injection Molding
Contact Seal	Interference
Receptacle to Bulkhead	O-ring

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	7-1/2 to 175 amps
Working Voltage	115 to 440 V dc
Withstanding Voltage	230 to 880 V dc
Contact Resistance	5 milliohms

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	10,000 psi
Unmated	(P) 10,000; (R) 3,000
Temperature Range	-40°F to 165°F
Durability:	
Number of Cycles	500
Expected Life	3 yr
Vibration	
Physical Shock	
Corrosion	

* Including Hex Nut or Coupling Ring

POLARIZING METHOD

Pins; alternate pin arrangements available

STRAIN RELIEF METHODS

Between Cable & Assembly:

Between Contacts & Wire:
None

SPECIAL DESIGN FEATURES

"Watermate" underwater mateable connector; pressure balanced

SPECIAL OPTIONS

Locking Sleeves

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

\$40.00 to \$240.00

MANUFACTURER:

Electro

SERIES:

53 E, F, H, L: Male and Female Bulkhead Receptacles

CATALOGUE PAGE **V**

PRODUCT MATRIX

CONNECTOR CLASSIFICATION **UM**

STANDARD MATERIALS

Shell	Brass
Boot/Jacket	Neoprene
Contacts & Plating	Beryllium Copper
Insulator	Various
Coupling Ring/Nut	None

CONNECTOR SIZE

Max. Length (Assembled)	1-13/16"
Maximum Diameter*	3/4"

CONTACTS

Termination (Cable to Contact)	Solder
Size Range	18, 16
Number Range	1-2

SEALING DESIGNS

Plug to Receptacle	Interference
Cable to Plug	Injection Molding
Contact Seal	Interference
Receptacle to Bulkhead	Skirt Seal

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	7-1/2 to 15 amps
Working Voltage	110-230 V dc
Withstanding Voltage	
Contact Resistance	5 milliohms

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	20,000 psi
Unmated	(P)10,000; (R)3,000
Temperature Range	-40°F to 165°F
Durability:	
Number of Cycles	
Expected Life	
Vibration	
Physical Shock	
Corrosion	

POLARIZING METHOD

None

STRAIN RELIEF METHODS

Between Cable & Assembly:

Between Contacts & Wire:

SPECIAL DESIGN FEATURES

"Watermate" underwater mateable connector; right angle assembly; pressure balanced

SPECIAL OPTIONS

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

\$36.00 to \$38.00

MANUFACTURER:

Electro

SERIES:

59 E, F

* Including Hex Nut or Coupling Ring

CATALOGUE PAGE **V**

PRODUCT MATRIX

CONNECTOR CLASSIFICATION **UM**

STANDARD MATERIALS

Shell	S.S.
Boot/Jacket	Neoprene
Contacts & Plating	Beryllium Copper
Insulator	Various
Coupling Ring/Nut	None

CONNECTOR SIZE

Max. Length (Assembled)	4-7/8"
Maximum Diameter*	1-3/4"

CONTACTS

Termination (Cable to Contact)	Solder
Size Range	8,1
Number Range	1

SEALING DESIGNS

Plug to Receptacle	Interference
Cable to Plug	Injection Molding
Contact Seal	Interference
Receptacle to Bulkhead	Skirt Seal

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	60 to 175 amps
Working Voltage	115 - 440 V dc
Withstanding Voltage	
Contact Resistance	5 milliohms

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	10,000 psi
Unmated	(P) 10,000; (R) 3,000
Temperature Range	-40°F to 165°F
Durability:	
Number of Cycles	
Expected Life	
Vibration	
Physical Shock	
Corrosion	

POLARIZING METHOD

None

STRAIN RELIEF METHODS

Between Cable & Assembly:

None

Between Contacts & Wire:

None

SPECIAL DESIGN FEATURES

"Watermate" underwater mateable connector; right angle connector, pressure balanced

SPECIAL OPTIONS

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

\$110.00 to \$140.00

MANUFACTURER:

Electro

SERIES:

59 H, L

* Including Hex Nut or Coupling Ring

CATALOGUE PAGE **V**

PRODUCT MATRIX

CONNECTOR CLASSIFICATION **UM**

STANDARD MATERIALS

Shell	Brass
Boot/Jacket	Neoprene
Contacts & Plating	Beryllium Copper
Insulator	Various
Coupling Ring/Nut	None

CONNECTOR SIZE

Max. Length (Assembled)	2-1/4"
Maximum Diameter*	2-1/4"

CONTACTS

Termination (Cable to Contact)	Solder
Size Range	18, 16
Number Range	1-2

SEALING DESIGNS

Plug to Receptacle	Interference
Cable to Plug	Injection Molding
Contact Seal	Interference
Receptacle to Bulkhead	Skirt Seal

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	7-1/2 to 15 amps
Working Voltage	115 - 230 Volts
Withstanding Voltage	
Contact Resistance	5 milliohms

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	5,000 psi
Unmated	
Temperature Range	-40°F to 165°F
Durability:	
Number of Cycles	
Expected Life	
Vibration	
Physical Shock	
Corrosion	

POLARIZING METHOD

Offset Molded in Connector

STRAIN RELIEF METHODS

Between Cable & Assembly:

Between Contacts & Wire:
Service Loop

SPECIAL DESIGN FEATURES

"Watermate" underwater mateable connector; rectangular right angle connector; pressure balanced

SPECIAL OPTIONS

20,000 psi rating; pigtails

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

\$60.00

MANUFACTURER:

Electro

SERIES:

510 E, F

* Including Hex Nut or Coupling Ring

CATALOGUE PAGE **V**

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **UM**

STANDARD MATERIALS

Shell
Boot/Jacket
Contacts & Plating
Insulator
Coupling Ring/Nut

For Basic Characteristics, see Kintec RM Connectors --
Series HS6

CONNECTOR SIZE

Max. Length (Assembled)
Maximum Diameter*

CONTACTS

Termination (Cable to Contact) Solder
Size Range 2
Number Range 1 - #10 and 1 - #14

SEALING DESIGNS

Plug to Receptacle
Cable to Plug
Contact Seal
Receptacle to Bulkhead

ELECTRICAL CHARACTERISTICS

Max. Current Capacity
Working Voltage
Withstanding Voltage
Contact Resistance

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure
Range:
Mated
Unmated
Temperature Range
Durability:
Number of Cycles
Expected Life
Vibration
Physical Shock
Corrosion

POLARIZING METHOD

STRAIN RELIEF METHODS

Between Cable & Assembly:

Between Contacts & Wire:

SPECIAL DESIGN FEATURES

SPECIAL OPTIONS

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

MANUFACTURER:

Kintec

SERIES:

HS6-2BP-UM

* Including Hex Nut or Coupling Ring

CATALOGUE
PAGE **vi**

PRODUCT MATRIX

CONNECTOR CLASSIFICATION **UM**

STANDARD MATERIALS

Shell	Nickel Plated Naval Brass
Boot/Jacket	Neoprene
Contacts & Plating	None
Insulator	
Coupling Ring/Nut	Delrin, S.S.

CONNECTOR SIZE

Max. Length (Assembled)	9.02"
Maximum Diameter*	1.49"

CONTACTS

Termination (Cable to Contact)	
Size Range	
Number Range	

SEALING DESIGNS

Plug to Receptacle	None
Cable to Plug	Neoprene Boot
Contact Seal	None
Receptacle to Bulkhead	2 O-rings

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	Power 10 watts
Working Voltage	9 to 75 V (rms)
Withstanding Voltage	
Contact Resistance	

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	150 kg/cm ²
Unmated	150 kg/cm ²
Temperature Range	-20°C to 55°C
Durability:	
Number of Cycles	
Expected Life	
Vibration	
Physical Shock	
Corrosion	

* Including Hex Nut or Coupling Ring

POLARIZING METHOD

Omnidirectional

STRAIN RELIEF METHODS

Between Cable & Assembly:
Neoprene Boot
Between Contacts & Wire:

SPECIAL DESIGN FEATURES

Designed for audio frequency applications with matched 8, 50 or 600 ohm source and load impedances; magnetic shielding

SPECIAL OPTIONS

RECOMMENDED ZONES OF APPLICATION

Data transmission, telephone computer interfacing

APPROXIMATE PRICE RANGE

MANUFACTURER:

Pelcon Limited (Stewart & Stevenson Oiltools, Inc., Houston)

SERIES:

ACC 150 Inductive Couplers

CATALOGUE PAGE **vii**

PRODUCT MATRIX

CONNECTOR CLASSIFICATION **UM**

STANDARD MATERIALS

Shell	Epoxy Coated S.S., 316
Boot/Jacket	Neoprene or Polyurethane
Contacts & Plating	None
Insulator	
Coupling Ring/Nut	Delrin, S.S.

CONNECTOR SIZE

Max. Length (Assembled)	7.480"
Maximum Diameter*	1.967"

CONTACTS

Termination (Cable to Contact)	
Size Range	
Number Range	

SEALING DESIGNS

Plug to Receptacle	
Cable to Plug	Potting, Boot
Contact Seal	
Receptacle to Bulkhead	2 O-rings

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	Power: 25, 100 watts
Working Voltage	35 to 150 V (rms)
Withstanding Voltage	
Contact Resistance	

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	350 kg/cm ²
Unmated	350 kg/cm ²
Temperature Range	-2°C to 55°C
Durability:	
Number of Cycles	
Expected Life	
Vibration	
Physical Shock	
Corrosion	

POLARIZING METHOD

Omnidirectional

STRAIN RELIEF METHODS

Between Cable & Assembly:
Neoprene Boot

Between Contacts & Wire:

SPECIAL DESIGN FEATURES

Applications with matched 50 or 150 ohm source and load impedances; magnetic shielding

SPECIAL OPTIONS

RECOMMENDED ZONES OF APPLICATION

Low and medium level power and instrumentation applications

APPROXIMATE PRICE RANGE

MANUFACTURER:

Pelcon Limited (Stewart and Stevenson Oiltools, Inc., Houston)

SERIES:

FMEP 350 Inductive Couplers

* Including Hex Nut or Coupling Ring

CATALOGUE PAGE **vii**

PRODUCT MATRIX

CONNECTOR CLASSIFICATION **UM**

STANDARD MATERIALS

Shell	S.S. (AISI 316L)
Boot/Jacket	
Contacts & Plating	Brass - Gold
Insulator	Neoprene
Coupling Ring/Nut	Glass-filled Thermoplastic

CONNECTOR SIZE

Max. Length (Assembled)	Crimp
Maximum Diameter*	

CONTACTS

Termination (Cable to Contact)	Crimp
Size Range	2.5 mm dia.
Number Range	1

SEALING DESIGNS

Plug to Receptacle	
Cable to Plug	
Contact Seal	
Receptacle to Bulkhead	

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	23 amps
Working Voltage	250 V (rms)
Withstanding Voltage	1500 V (rms)
Contact Resistance	<10 milliohms

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	300 bars
Unmated	
Temperature Range	-30°C to 70°C
Durability:	
Number of Cycles	
Expected Life	
Vibration	
Physical Shock	
Corrosion	

POLARIZING METHOD

STRAIN RELIEF METHODS

Between Cable & Assembly:

Between Contacts & Wire:

SPECIAL DESIGN FEATURES

SPECIAL OPTIONS

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

MANUFACTURER:

Souriau, San Diego

SERIES:

Souriau 8805

* Including Hex Nut or Coupling Ring

CATALOGUE PAGE **vii**

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **UM**

STANDARD MATERIALS

Shell	Thermoplastic
Boot/Jacket	
Contacts & Plating	Copper Alloy - Gold
Insulator	Polychloroprene
Coupling Ring/Nut	Thermoplastic or S.S.

CONNECTOR SIZE

Max. Length (Assembled)	4.65"
Maximum Diameter*	3.0"

CONTACTS

Termination (Cable to Contact)	Solder
Size Range	14
Number Range	1-9

SEALING DESIGNS

Plug to Receptacle	
Cable to Plug	Molded
Contact Seal	Fluorosilicone
Receptacle to Bulkhead	O-ring

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	20 amps
Working Voltage	600 V ac (rms)
Withstanding Voltage	
Contact Resistance	

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	20,000 psi
Unmated	20,000 psi
Temperature Range	-40°C to 125°C
Durability:	
Number of Cycles	Approx. 100
Expected Life	Approx. 5 yr
Vibration	
Physical Shock	
Corrosion	

POLARIZING METHOD

Keys

STRAIN RELIEF METHODS

Between Cable & Assembly:
Molding

Between Contacts & Wire:
Molding

SPECIAL DESIGN FEATURES

Underwater mateable; pressure compensating diaphragm

SPECIAL OPTIONS

S.S. or titanium shells optional;
Bulkhead or in-line receptacles;
straight or right angle plugs

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

\$100.00

MANUFACTURER:

Viking Industries, Inc.

SERIES:

Pisces - Underwater Mateable

* Including Hex Nut or Coupling Ring

CATALOGUE
PAGE **vii**

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **UM**

STANDARD MATERIALS

Shell
Boot/Jacket
Contacts & Plating
Insulator
Coupling Ring/Nut

See Catalogue for Information on CEL 1, 2, and 3
Wet Connectors

CONNECTOR SIZE

Max. Length (Assembled)
Maximum Diameter*

CONTACTS

Termination (Cable to
Contact)
Size Range
Number Range

SEALING DESIGNS

Plug to Receptacle
Cable to Plug
Contact Seal
Receptacle to Bulkhead

ELECTRICAL CHARACTERISTICS

Max. Current Capacity
Working Voltage
Withstanding Voltage
Contact Resistance

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure
Range:
Mated
Unmated
Temperature Range
Durability:
Number of Cycles
Expected Life
Vibration
Physical Shock
Corrosion

POLARIZING METHOD

STRAIN RELIEF METHODS

Between Cable & Assembly:

Between Contacts & Wire:

SPECIAL DESIGN FEATURES

SPECIAL OPTIONS

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

MANUFACTURER:

SERIES:

NCEL 1, 2, 3 Wet Connectors

* Including Hex Nut or Coupling Ring

CATALOGUE
PAGE **vii**

3-00

PRODUCT MATRIX

CONNECTOR CLASSIFICATION **MISC**

STANDARD MATERIALS

Shell	S.S.
Boot/Jacket	
Contacts & Plating	
Insulator	Insulator-Seals: Lava; Teflon; Neoprene or Viton
Coupling Ring/Nut	S.S.

CONNECTOR SIZE

Max. Length (Assembled)	3-5/8"
Maximum Diameter*	1-1/8"

POLARIZING METHOD

CONTACTS

Termination (Cable to Contact)	
Size Range	24, 20, 14, 8
Number Range	1-16

STRAIN RELIEF METHODS

Between Cable & Assembly:

Between Contacts & Wire:

SEALING DESIGNS

Plug to Receptacle	
Cable to Plug	Torque Compression
Contact Seal	Torque Compression
Receptacle to Bulkhead	Torque Compression

SPECIAL DESIGN FEATURES

Low voltage multiple bare wire sealing; reusable fitting

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	
Working Voltage	Millivolt range
Withstanding Voltage	
Contact Resistance	

SPECIAL OPTIONS

See catalogue for additional glands and sealing materials

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	10,000 psi
Unmated	
Temperature Range	-300°F to 1850°F
Durability:	
Number of Cycles	
Expected Life	
Vibration	
Physical Shock	
Corrosion	

RECOMMENDED ZONES OF APPLICATION

High pressure transducer applications

APPROXIMATE PRICE RANGE

MANUFACTURER:

Conax Corporation

SERIES:

TG: Transducer Gland

* Including Hex Nut or Coupling Ring

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **MISC**

STANDARD MATERIALS

Shell	S.S.
Boot/Jacket	Neoprene
Contacts & Plating	Brass
Insulator	Various
Coupling Ring/Nut	None

CONNECTOR SIZE

Max. Length (Assembled)	3-1/8"
Maximum Diameter*	1-1/4"

CONTACTS

Termination (Cable to Contact)	Solder
Size Range	18 (others optional)
Number Range	1-12

SEALING DESIGNS

Plug to Receptacle	Injection Molding
Cable to Plug	
Contact Seal	
Receptacle to Bulkhead	O-ring

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	7-1/2 amps
Working Voltage	115 V dc
Withstanding Voltage	
Contact Resistance	

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	20,000 psi
Mated	
Unmated	
Temperature Range	
Durability:	
Number of Cycles	
Expected Life	
Vibration	
Physical Shock	
Corrosion	

POLARIZING METHOD

STRAIN RELIEF METHODS

Between Cable & Assembly:
Molding

Between Contacts & Wire:

SPECIAL DESIGN FEATURES

See catalogue for additional switches and junction boxes.

SPECIAL OPTIONS

Additional pins and pin sizes;
additional shell materials.

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

\$32.00 to \$60.00

MANUFACTURER:

Electro.

SERIES: 41-Penetrator

* Including Hex Nut or Coupling Ring

CATALOGUE
PAGE **v**

PRODUCT MATRIX

CONNECTOR CLASSIFICATION **MISC**

STANDARD MATERIALS

Shell	S.S.
Boot/Jacket	Molded Neoprene
Contacts & Plating	Feedthru Alloy 52 or Copper - Gold
Insulator	Glass Epoxy or Glass Header
Coupling Ring/Nut	S.S. Jam Nuts

CONNECTOR SIZE

Max. Length (Assembled)	6"
Maximum Diameter*	3"

CONTACTS

Termination (Cable to Contact)	
Size Range	22, 20, 16, 12, 8, 4, 0
Number Range	1-36

SEALING DESIGNS

Plug to Receptacle	2 O-rings
Cable to Plug	Molded Neoprene
Contact Seal	Header Assemblies
Receptacle to Bulkhead	O-ring

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	3 to 200 amps
Working Voltage	600 V dc
Withstanding Voltage	1000 V dc
Contact Resistance	

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	10,000 psi
Unmated	
Temperature Range	-40°F to 250°F
Durability:	
Number of Cycles	
Expected Life	5 yr
Vibration	
Physical Shock	
Corrosion	

POLARIZING METHOD

STRAIN RELIEF METHODS

Between Cable & Assembly:
Molded Boot
Between Contacts & Wire:

SPECIAL DESIGN FEATURES

SPECIAL OPTIONS

Shells of brass, aluminum, monel, cupronickel; cable jackets and moldings of buna, viton, polyurethane

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

MANUFACTURER:

Glenair, Inc.

SERIES:

GLW70-Penetrators

* Including Hex Nut or Coupling Ring

CATALOGUE PAGE

v

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **MISC**

STANDARD MATERIALS

Shell	Steel Alloy or S.S.
Boot/Jacket	
Contacts & Plating	
Insulator	
Coupling Ring/Nut	
	Teflon; Grease

CONNECTOR SIZE

Max. Length (Assembled)	10" to 17"
Maximum Diameter*	7/8" to 3-1/2"

CONTACTS

Termination (Cable to Contact)	
Size Range	
Number Range	
	1-7

SEALING DESIGNS

Plug to Receptacle	
Cable to Plug	
Contact Seal	
Receptacle to Bulkhead	

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	
Working Voltage	
Withstanding Voltage	
Contact Resistance	

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	15,000 psi
Mated	
Unmated	to 300°F
Temperature Range	
Durability:	
Number of Cycles	
Expected Life	
Vibration	
Physical Shock	
Corrosion	

* Including Hex Nut or Coupling Ring

POLARIZING METHOD

STRAIN RELIEF METHODS

Between Cable & Assembly:
Coiled Spring
Between Contacts & Wire:

SPECIAL DESIGN FEATURES

See Catalogue

SPECIAL OPTIONS

RECOMMENDED ZONES OF APPLICATION

Down-hole logging

APPROXIMATE PRICE RANGE

MANUFACTURER:

Gearhart-Owen Ind., Inc.

SERIES:

7/8" O.D. to 3-1/2" O.D.
Cablehead Assemblies

CATALOGUE
PAGE

V

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **MISC**

STANDARD MATERIALS

Shell
Boot/Jacket
Contacts & Plating
Insulator
Coupling Ring/Nut

---- For Hexcel Cable Splicing Systems, see catalogue.

CONNECTOR SIZE

Max. Length (Assembled)
Maximum Diameter*

POLARIZING METHOD

CONTACTS

Termination (Cable to Contact)
Size Range
Number Range

STRAIN RELIEF METHODS

Between Cable & Assembly:

Between Contacts & Wire:

SEALING DESIGNS

Plug to Receptacle
Cable to Plug
Contact Seal
Receptacle to Bulkhead

SPECIAL DESIGN FEATURES

ELECTRICAL CHARACTERISTICS

Max. Current Capacity
Working Voltage
Withstanding Voltage
Contact Resistance

SPECIAL OPTIONS

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:
Mated
Unmated
Temperature Range
Durability:
Number of Cycles
Expected Life
Vibration
Physical Shock
Corrosion

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

MANUFACTURER:

Hexcel, Inc.

SERIES:

Hotsplicer and related products

* Including Hex Nut or Coupling Ring

CATALOGUE
PAGE **v**

PRODUCT MATRIX

CONNECTOR CLASSIFICATION **MISC**

STANDARD MATERIALS

Shell	K-Monel
Boot/Jacket	(P) Polyethylene; (R) Polyurethane
Contacts & Plating	(P) Molybdenum: Au over Cu over Ag; (R) Au over Ag
Insulator	(P) Glass (R) Glass Reinforced Epoxy, Silicone
Coupling Ring/Nut	Aluminum Bronze

CONNECTOR SIZE

Max. Length (Assembled)	27.75"
Maximum Diameter*	5.88"

CONTACTS

Termination (Cable to Contact)	Crimp
Size Range	20
Number Range	36

SEALING DESIGNS

Plug to Receptacle	0-ring, radial
Cable to Plug	Bonded Polyurethane
Contact Seal	Glass
Receptacle to Bulkhead	0-ring

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	7.5 amps
Working Voltage	300 Volts
Withstanding Voltage	100 Volts
Contact Resistance	70 milliohms

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	2,000 psi
Unmated	2,000 psi
Temperature Range	-22°F to 140°F
Durability:	
Number of Cycles	100
Expected Life	20 yr
Vibration	MIL-STD-167 (I)
Physical Shock	MIL-S-901 (A-1-A)
Corrosion	Resistant

POLARIZING METHOD

Keys

STRAIN RELIEF METHODS

Between Cable & Assembly:
Clamp; Bonded Polyurethane

Between Contacts & Wire:
Plotting

SPECIAL DESIGN FEATURES

Intermelted seal between outboard polyethylene cable jackets and outboard side of penetrator

SPECIAL OPTIONS

Other contact sizes and complements available on special order

RECOMMENDED ZONES OF APPLICATION

Carrying signals through pressure walls at depths less than 4,000 feet

APPROXIMATE PRICE RANGE

\$5000 in production quantities

MANUFACTURER:

ITT Cannon Electric, Phoenix

SERIES:

H 104286-2: Penetrator

* Including Hex Nut or Coupling Ring

CATALOGUE PAGE **vi**

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **MISC**

STANDARD MATERIALS

Shell	Receptacle: Aluminum Alloy 7075T6
Boot/Jacket	
Contacts & Plating	Leaded Brass - Gold (termination end); Butt-type - Gold (engaging end)
Insulator	Front: KEL-F81 Matl; Rear: Glass Hermetic with B1113 Steel
Coupling Ring/Nut	

CONNECTOR SIZE

Max. Length (Assembled)	1.900"
Maximum Diameter*	3.860"

CONTACTS

Termination (Cable to Contact)	Crimp
Size Range	20
Number Range	65

SEALING DESIGNS

Plug to Receptacle	Interfacial Butt
Cable to Plug	
Contact Seal	0-rings
Receptacle to Bulkhead	0-rings

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	5.5 to 9.2 amps
Working Voltage	28 - 115 Volts
Withstanding Voltage	700 - 750 Volts
Contact Resistance	500 milliohms

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	2000 psi
Unmated	2000 psi
Temperature Range	-20°F to 130°F
Durability:	
Number of Cycles	
Expected Life	5 to 10 yr
Vibration	MIL-STD-167 (I)
Physical Shock	6g ± 0.6g, 8 ± 1 msec
Corrosion	

POLARIZING METHOD

Lock Ring & Pins

STRAIN RELIEF METHODS

Between Cable & Assembly:

None

Between Contacts & Wire:

None

SPECIAL DESIGN FEATURES

Removable contact inserts;
spring loaded butt contacts
at engaging face

SPECIAL OPTIONS

Special butt type termination
for contacts

RECOMMENDED ZONES OF APPLICATION

Undersea Bulkhead Type

APPROXIMATE PRICE RANGE

\$450.00 in 500 piece lots

MANUFACTURER:

ITT Cannon Electric, Phoenix

SERIES:

Torpedo Receptacle: Navy P/N 758008
(ITT P/N GM100222-105)

* Including Hex Nut or Coupling Ring

CATALOGUE
PAGE **N/A**

PRODUCT MATRIX

CONNECTOR CLASSIFICATION **MISC**

STANDARD MATERIALS

Shell	Molded Epoxy, Thermoset on One End; Aluminum Alloy 356T6 on the other end.
Boot/Jacket	Neoprene
Contacts & Plating	S.S. No Plating (Epoxy End); Mild Steel - Gold (Al End),
Insulator	Plastic Mold (Epoxy End); Glass-Sealed Steel Insert (Al End)
Coupling Ring/Nut	

CONNECTOR SIZE

Max. Length (Assembled)	66"
Maximum Diameter*	.984 (Epoxy End) & 3.50"

CONTACTS

Termination (Cable to Contact)	Crimp; weld
Size Range	16, 12
Number Range	56

SEALING DESIGNS

Plug to Receptacle	Interface Butt Seal
Cable to Plug	
Contact Seal	Mold and Glass
Receptacle to Bulkhead	O-ring

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	5.5 to 9.2 amps
Working Voltage	28 to 115 V
Withstanding Voltage	700-750 V
Contact Resistance	200 milliohms

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	1,000 psi
Unmated	1,000 psi
Temperature Range	-20°F to 130°F
Durability:	
Number of Cycles	5-10
Expected Life	5-10 yr
Vibration	MIL-STD-167 (I)
Physical Shock	6g \pm 0.6g, 8 \pm 1 msec
Corrosion	

* Including Hex Nut or Coupling Ring

POLARIZING METHOD

Pins; Keys

STRAIN RELIEF METHODS

Between Cable & Assembly:

Between Contacts & Wire:
Epoxy and Molded
Polychloroprene

SPECIAL DESIGN FEATURES

Molded plug on one end of cable
no larger than cable diameter

SPECIAL OPTIONS

RECOMMENDED ZONES OF APPLICATION

General

APPROXIMATE PRICE RANGE

\$650.00 in 500 piece lots

MANUFACTURER:

ITT Cannon Electric, Phoenix

SERIES: Torpedo Cable Assy: Navy

P/N 642-AS0539 (ITT P/N CH100190-18)

CATALOGUE PAGE **N/A**

PRODUCT MATRIX

CONNECTOR CLASSIFICATION **MISC**

STANDARD MATERIALS

Shell	Monel K-500
Boot/Jacket	
Contacts & Plating	Molybdenum - Gold (one end), Leaded NiCu - Gold (other end)
Insulator	MIL-R-6855 Molded Rubber (one end); Polyurethane
Coupling Ring/Nut	059333, CL.A (other end)

CONNECTOR SIZE

Max. Length (Assembled)	4.598"
Maximum Diameter*	5.00"

CONTACTS

Termination (Cable to Contact)	
Size Range	16
Number Range	65

SEALING DESIGNS

Plug to Receptacle	
Cable to Plug	Peripheral O-ring
Contact Seal	Glass
Receptacle to Bulkhead	O-ring

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	5.5 to 9.2 amps
Working Voltage	28-115 V
Withstanding Voltage	700-750 V
Contact Resistance	500 milliohms

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	3,000 psi
Unmated	3,000 psi
Temperature Range	-20°F to 130°F
Durability:	
Number of Cycles	
Expected Life	20 yr
Vibration	MIL-STD-167 (I)
Physical Shock	MIL-S-901
Corrosion	

POLARIZING METHOD

Keys

STRAIN RELIEF METHODS

Between Cable & Assembly:

Between Contacts & Wire:

SPECIAL DESIGN FEATURES

Removable Contact Inserts

SPECIAL OPTIONS

Similar receptacles for SUBROC Harpoon Missiles

RECOMMENDED ZONES OF APPLICATION

Undersea Bulkhead

APPROXIMATE PRICE RANGE

\$1,100.00 in 500 piece lots

MANUFACTURER:

ITT Cannon Electric, Phoenix

SERIES: Tube Door Receptacle: Navy
P/N 2865440 (ITT Cannon P/N 6M102405-4)

* Including Hex Nut or Coupling Ring

CATALOGUE PAGE **N/A**

PRODUCT MATRIX

CONNECTOR CLASSIFICATION **MISC**

STANDARD MATERIALS

Shell
Boot/Jacket
Contacts & Plating
Insulator
Coupling Ring/Nut

See ITT Cannon Catalogue for Information on Fiber Optics Cable and Connectors.

CONNECTOR SIZE

Max. Length (Assembled)
Maximum Diameter*

CONTACTS

Termination (Cable to Contact)
Size Range
Number Range

SEALING DESIGNS

Plug to Receptacle
Cable to Plug
Contact Seal
Receptacle to Bulkhead

ELECTRICAL CHARACTERISTICS

Max. Current Capacity
Working Voltage
Withstanding Voltage
Contact Resistance

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:
Mated
Unmated
Temperature Range
Durability:
Number of Cycles
Expected Life
Vibration
Physical Shock
Corrosion

POLARIZING METHOD

STRAIN RELIEF METHODS

Between Cable & Assembly:

Between Contacts & Wire:

SPECIAL DESIGN FEATURES

SPECIAL OPTIONS

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

MANUFACTURER:

ITT Cannon

SERIES:

Fiber Optics Undersea Data
Transmission Systems

* Including Hex Nut or Coupling Ring

CATALOGUE PAGE **vi**

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **MISC**

STANDARD MATERIALS

Shell	316 S.S.; Anodized Al; Brass (special)
Boot/Jacket	Neoprene Molding Compound
Contacts & Plating	Brass - Gold
Insulator	Kintec, Inc. K-500
Coupling Ring/Nut	

CONNECTOR SIZE

Max. Length (Assembled)	2.0" to 8.0"
Maximum Diameter*	.75" to 2.50"

CONTACTS

Termination (Cable to Contact)	Solder
Size Range	16, 14, 12, 10, 8, 4, 2, 0, 00
Number Range	1-40

SEALING DESIGNS

Plug to Receptacle	
Cable to Plug	Neopr., Plyuret. mold
Contact Seal	Molding
Receptacle to Bulkhead	O-ring, Pipe Plug thd

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	0-600 amps
Working Voltage	to 18,000 V
Withstanding Voltage	2 x wkg. vltg. + 1000
Contact Resistance	.5 to .25 milliohms

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	
Mated	20,000 psi
Unmated	10,000 psi
Temperature Range	to 450°F
Durability:	
Number of Cycles	
Expected Life	to 20 yr
Vibration	as required
Physical Shock	as required
Corrosion	as required

POLARIZING METHOD

STRAIN RELIEF METHODS

Between Cable & Assembly:
Hard Encapsulation
Between Contacts & Wire:
Hard Encapsulation

SPECIAL DESIGN FEATURES

Shielding device; removable contact inserts; field-inst. assy.; pipe plug shell design; secondary seal

SPECIAL OPTIONS

High voltage; virtually any cable construction

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

\$200.00 to \$6,000.00

MANUFACTURER:

Kintec, Inc.

SERIES:

MP -- Metal Penetrator

* Including Hex Nut or Coupling Ring

CATALOGUE
PAGE **vi**

PRODUCT MATRIX

CONNECTOR
CLASSIFICATION **MISC**

STANDARD MATERIALS

Shell	Tygon Tubing Dow Corning 3140 RTV
Boot/Jacket	
Contacts & Plating	
Insulator	
Coupling Ring/Nut	

CONNECTOR SIZE

Max. Length (Assembled)	Approx. 4"
Maximum Diameter*	#4/0 to #22 Cable

CONTACTS

Termination (Cable to Contact)	Crimp
Size Range	
Number Range	

SEALING DESIGNS

Plug to Receptacle	DC-3140 RTV
Cable to Plug	DC-3140 RTV
Contact Seal	
Receptacle to Bulkhead	

ELECTRICAL CHARACTERISTICS

Max. Current Capacity	
Working Voltage	
Withstanding Voltage	
Contact Resistance	

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:	0-5000 psi
Mated	
Unmated	0°C to 20°C
Temperature Range	
Durability:	1 - 2 yr
Number of Cycles	
Expected Life	
Vibration	
Physical Shock	
Corrosion	

POLARIZING METHOD

STRAIN RELIEF METHODS

Between Cable & Assembly:

Between Contacts & Wire:

SPECIAL DESIGN FEATURES

Underwater cable splicing method -- see Master Catalogue

SPECIAL OPTIONS

RECOMMENDED ZONES OF APPLICATION

Oil or water environment

APPROXIMATE PRICE RANGE

MANUFACTURER:

NCEL, Port Hueneme, California

SERIES:

Tygon Underwater EM Cable Splice

* Including Hex Nut or Coupling Ring

CATALOGUE
PAGE **vii**

PRODUCT MATRIX

CONNECTOR CLASSIFICATION **MISC**

STANDARD MATERIALS

Shell
Boot/Jacket
Contacts & Plating
Insulator
Coupling Ring/Nut

See Catalogue for Mechanical Cable Terminations and Information on Extensive Facilities for Contract Testing.

CONNECTOR SIZE

Max. Length (Assembled)
Maximum Diameter*

CONTACTS

Termination (Cable to Contact)
Size Range
Number Range

SEALING DESIGNS

Plug to Receptacle
Cable to Plug
Contact Seal
Receptacle to Bulkhead

ELECTRICAL CHARACTERISTICS

Max. Current Capacity
Working Voltage
Withstanding Voltage
Contact Resistance

ENVIRONMENTAL CHARACTERISTICS

Hydrostatic Pressure Range:
Mated
Unmated
Temperature Range
Durability:
Number of Cycles
Expected Life
Vibration
Physical Shock
Corrosion

POLARIZING METHOD

STRAIN RELIEF METHODS

Between Cable & Assembly:

Between Contacts & Wire:

SPECIAL DESIGN FEATURES

SPECIAL OPTIONS

RECOMMENDED ZONES OF APPLICATION

APPROXIMATE PRICE RANGE

MANUFACTURER:

Preformed Line Prod., Inc.

SERIES:

Dyna-Grip Electromechanical Terminations

* Including Hex Nut or Coupling Ring

CATALOGUE PAGE **vii**

Section 5
TABLE OF CONTENTS

<u>Section</u>	<u>Title</u>	<u>Page</u>
5.1	Introduction	5-1
5.1.1	Scope	5-1
5.2	Combined Custom and Standard Line Manufacturers	5-2
5.3	Custom Underwater Connector Manufacturers	5-20

Section 5

GUIDE TO UNDERWATER ELECTRICAL CONNECTOR MANUFACTURERS— STANDARD AND CUSTOM DESIGNS

5.1 Introduction

Approximately forty organizations are involved in the commercial production of underwater electrical connectors. Several firms manufacture both standard and custom lines of connectors, while other organizations concentrate exclusively on supplying custom manufactured assemblies which meet either standard or special requirements. Lack of standardization, a high degree of specialization required for specific underwater connector applications, and exotic environments, all contribute to the fact that the connector industry is essentially still a custom design industry. Even the best known manufacturers of standard lines of underwater connectors do the bulk of their business in custom connector systems.

5.1.1 Scope

The following section includes a current compilation of companies involved in the manufacture of underwater electrical connectors. Information on the various companies--their connector lines, clientele, and research--was accumulated through the mailing of questionnaires to as many organizations as could be identified as connector manufacturers. Inevitably, some organizations will have been missed; subsequent updates of this manual should remedy any significant omissions.

The first part of this section includes companies that market standard lines of connectors and that do substantial custom design in connector systems. The second part lists firms and organizations that manufacture custom underwater connector systems exclusively. The catalogues of all companies listed in the first part are contained in the Master Catalogue which is organized alphabetically. Product matrices are contained in the preceding section of this manual.

5.2 Combined Custom and Standard Line Manufacturers

1. BENDIX CORPORATION
Electrical Components Division
Sherman Avenue
Sidney, NY 13838
(607)-563-9511 (for information and bids)

See SECTION 1 of
Master Catalogue

BENDIX CORPORATION
Electrodynamics Division
15825 Roxford Street
Sylmar, CA 91342
(213)-367-0111

Products: Bendix produces a standard Aquacon line of metal shell underwater electrical connectors. The Aquacon series has a 316 stainless steel shell and offers a good selection of contact arrangements for bulkhead or in-line applications. In addition, Bendix has an extensive and ongoing research program on underwater connector theory and design; its staff has published numerous papers on problems related to the field.

Users include: EDO Corp., 13-10 111th St., College Point, NY 11356; (212)-445-6000: Bendix AP Aquacon connector series for magnetic minesweeping gear (Sea Sled Project), from mid-1974 to present.

Gen. Electric Co., 3198 Chestnut St., Philadelphia, PA 19101; (215)-823-1000: Bendix AP Aquacon connector series for diving gear (Mark 10 Rebreather Project), from 1971 to 1975.

G.C. Marshall Space Flight Ctr., Huntsville, AL;
(205)-453-4560: Bendix AS and AJ Aquacon connector
series for Space Shuttle Recoverable Booster, from
1975 through program life.

Bendix Corporation, Electrodynamics Division, Sylmar,
CA; (213)-367-0111: Bendix AL Aquacon connector
series for Captor Program, from 1973 to present.

Present connector research: Since weight vs strength is
becoming an important factor in deep submergence
applications, the use of titanium in hermetic con-
nectors has been undertaken with excellent results.
The use of pure molybdenum contacts in hermetic con-
nectors has provided distinct advantages over the
standard 52 alloy. These include better corrosion
resistance, greater rigidity and less contact resist-
ance. A compensated, mateable underwater connector
has been designed, built and tested. It will be
marketed at a later date.

Information contributed by: Frank M. Hillis, Sr. Engineer-
ing Designer, Bendix (3-23-76).

2. BOSTON INSULATED WIRE AND CABLE CO.
65 Bay Street
Boston, MA 02125
(617)-265-2104 (for information and bids)

See SECTION 2 of
Master Catalogue

(West Coast) 12902 South Spring Street
Los Angeles, CA 90061
(213)-532-9064 (for information and bids)

Products: BIW is an integrated cable and connector com-
pany and produces both standard and custom underwater
cable terminations. BIW supplies both complete cable
systems and separate cable or connector assemblies.
It has a quality control system that meets MIL-Q-9858
requirements to monitor termination processes. It
has a standard line of metal shell connectors, the
ER and EB series, which are available with braided
and laced harness work and breakouts, and come in a
variety of pin configurations and mounting arrangements.

3. BRANTNER AND ASSOCIATES, INC.
3462 Hancock Street
San Diego, CA 92110
(714)-297-2828 (for information and bids)

See SECTION 3 of
Master Catalogue

THE ROCHESTER CORPORATION
Electro-Mechanical Division
P.O. Box 312
Culpeper, VA 22701
(703)-825-2111 (for information and bids)

THE ROCHESTER CORPORATION
EnviroCon Division
5725 Hartsdale Drive
Houston, TX 77036
(713)-782-5350 (for information and bids)

Products: Brantner/Rochester have a combined cable and connector capability and specialize in standard and custom underwater cable and connector applications. They have one of the most extensive standard connector selections available, with metal shell, glass epoxy and rubber molded connectors; bulkhead penetrators; glass hermetics; electro-mechanical armor cable terminations; field-installable connectors; cable splices and breakouts; as well as a full range of connector accessories. They have, in addition, a selection of pressure-balanced oil-filled connector assemblies, and a new co-radial underwater mateable connector series which has not yet been catalogued.

Users include: Hydro Products, Inc., 11777 Sorrento Valley Rd., San Diego, CA 92121; (714)-453-2345: EnviroCon connectors used for underwater TV and instrumentation, from 1969 to present.

U.S. Navy, NUC, San Diego, CA; NWC, China Lake, CA; NCEL, Port Hueneme, CA; NUS, Fort Lauderdale, FL; U.S.A. Amphib. Base, San Diego, CA: EnviroCon pressure-balanced oil-filled connector series used on various projects, including CURV II and III, Swimmer Vehicles, from 1969 to present.

Ametek-Straza, 790 Greenfield Dr., El Cajon, CA; (714)-442-3451: EnviroCon pressure-balanced oil-filled connector series used on underwater vehicles and instruments.

Bunker-Ramo, Westlake Village, CA; (213)-889-2211: EnviroCon connectors used in VLAM Program.

General Dynamics, San Diego, CA: EnviroCon connectors used on Monster Buoy Project.

Gould Ind., Columbus, OH; (216)-486-8300: EnviroCon connectors used on Mk 48 torpedo.

Hughes Aircraft, 1901 W. Malvern, Fullerton, CA 92634: EnviroCon connectors used on Towed Arrays 639, BQQ5.

Lockheed Missiles and Space Co., 3380 N. Harbor, San Diego, CA; (714)-298-8240: EnviroCon connectors used on Deep Quest and DSRV Projects.

Mare Is. Naval Shipyard, Vallejo, CA; Naval Coastal System Lab., Panama City, FL; Naval Torpedo Station, Keyport, WA: EnviroCon connectors for various uses.

Present connector research: Brantner and Associates are working on underwater make and break connectors which have been designed, built and tested and are now being marketed. Research and development continues on high temperature connectors and low cost metal shell connectors.

Information contributed by: L.L. (Bud) Seilhan, President, Brantner (2-27-76).

4. BURTON ELECTRICAL ENGINEERING,
A Wyle Company
111 Maryland Street
El Segundo, CA 90245
(213)-322-0615 (for information and bids)

See SECTION 4 of
Master Catalogue

Products: Burton manufactures underwater cable systems and connectors in both standard lines and custom designs. It markets a number of standard series of rubber molded, metal shell, hermetic and bulkhead penetrator assemblies. Some of these have been tested in accordance with test sections of MIL-C-24217 connector specifications.

5. CONAX CORPORATION
2300 Walden Avenue
Buffalo, NY 14225
(716)-684-4500 (for information and bids)

See SECTION 5 of
Master Catalogue

Products: Markets transducer glands, powerlead pressure seals, packing glands and fittings, utilizing sealing materials which include lava, Teflon, neoprene and viton.

6. COMPAGNIE DEUTSCH
8 rue Henri Regnault
92-Saint Cloud
France

See SECTION 6 of
Master Catalogue

771-64-76 (for information and bids); Telex: 260787

Products: Deutsch markets a DCI underwater connector series which comes in a wide variety of contact arrangements and mountings. It is a metal shell series and may be obtained with hermetic contact seals. Various accessories are available, including contact crimping, insertion and extraction tools.

Users include: French M.O.D., Atomic Submarine: Deutsch Hull Penetrator used for connection between outside antenna and inside instrumentation, from 1968 to present.

Underwater Sonar (KORMORAN Project): Deutsch connectors used at 6,000 meters depth for electrical connection between various parts of sonar equipment, from 1975 to present.

CNEXO, Route du Conquet, P.O. Box 337, Plouza NE, 29 N, Brest, France: Deutsch connectors used in Buoys Eole Program, from 1972 to 1973.

Kockums Mekaniska Verkstads Ab., 201-10 Malmo, Sweden: Deutsch connectors used in U.R.F. Rescue Submarine Project now in building stage.

Present connector research: Deutsch is working on an underwater mateable connector which may be connected and disconnected at depths of up to 1,400 meters. The UM connector will be identified as Series 934 and will be available in contact arrangements of 3-37 pins.

Information contributed by: A. Room, Deutsch (3-24-76).

7. ELECTRO CORPORATION
15146 Downey Avenue
Paramount, CA 90723
(213)-630-4252 (for information and bids)

See SECTION 7 of
Master Catalogue

Products: Electro markets the "Watermate" underwater mateable rubber molded connectors which come in several contact sizes and configurations. It also manufactures a standard series of underwater rubber molded connectors, a bulkhead penetrator series, underwater junction boxes and switches, and a field splicing kit.

Users include: Trieste II Project, Mare Island, CA:
Electro connectors used for electrical power and distribution systems, from 1969 to present.

Taylor Diving and Salvage, Belle Chasse, LA: Electro connectors used in SPAR and UWH Projects for power, heaters and lights, from 1972 to present.

Present connector research: Development at Electro initiated on customer request only.

Information contributed by: Bruce Marshall, Operations,
Electro (2-17-76).

8. EXCON, INC.,
A Subsidiary of B-K Dynamics, Inc.
215 Jupiter Street
Jupiter, FL 33458
(305)-746-9619 (for information and bids)

See SECTION 8 of
Master Catalogue

Products: ExCon is a product specialty company which produces a number of items utilizing plastics and elastomers for encapsulation, molding and potting operations. Products such as ExCon's seismic hydrophone transducer assembly, salinity cells, and towed instrumentation are designed to withstand environmental extremes. ExCon manufactures bulkhead penetrators, underwater cable harnesses and a number of high density underwater connectors, including a 180-HD Quick Disconnect aluminum connector with 130 coaxial pins and an accompanying patchboard connector. This assembly is designed for long seismic streamer systems.

9. FKC ENGINEERING CO.
185 York Avenue
Pawtucket, RI 02861
(401)-724-1760 (for information and bids)

Products: FKC produces a wide variety of connectors and cable assemblies for underwater applications. It has the tooling to produce all Mil-Spec underwater connectors, and has produced various connector items to customer requirements for several years. FKC does not market a standard line of connectors, as such; however, it has a broad connector capability and can manufacture a full range of connector accessories. No catalogue is printed by FKC.

Users include: U.S. Navy, unspecified divisions: have used FKC underwater electrical connectors for submarine and transducer systems, from 1962 to present.

Gems--Sensors Division, Spring Lane, Farmington, CT 06032; (203)-677-1311: FKC connectors used for electrical connections on liquid level monitors, underwater, 1968 to present.

General Electric Co., HMED Division, Syracuse, NY 13201: FKC connectors used for sonar, hydrophone and transducer applications, from 1970 to present.

General Instrument, Harris ASW Division, 33 S.W. Industrial Park, Westwood, MA 02090; (617)-326-7815: FKC connectors used for sonar, hydrophone and transducer applications, 1969 to present.

Raytheon Co., Submarine Signal Division, P.O. Box 360, Portsmouth, RI 02871; (401)-847-8000: FKC connectors used for sonar, hydrophone and transducer applications, from 1972 to present.

Westinghouse Electric Corp., Aerospace and Electronic Div., Friendship International Airport, Baltimore, MD 21203; (301)-765-1000: FKC connectors used for torpedo and bulkhead interfaces, from 1968 to 1972.

Present connector research: FKC is working on a new connector for NUSC, RI, which is to replace existing field connectors. The new FKC connector will be used as a "field change kit." It will be used by the U.S. Navy for various transducer applications.

Information contributed by: F.J. Coppel, General Manager,
FKC (3-10-76).

10. GEARHART-OWEN INDUSTRIES, INC.
P.O. Box 1936
Fort Worth, TX 76101
(817)-293-1300 (for information and bids)

See SECTION 9 of
Master Catalogue

Products: Among Gearhart-Owen's products are a new generation of downhole connectors or cablehead assemblies which are less than 2 in. O.D. These are designed primarily for oil industry use; however, their unique size, rugged design and strength, as well as their numerous accessories, would qualify them for other applications.

11. GLENAIR, INC.
1211 Air Way
Glendale, CA 91201
(213)-247-6000

See SECTION 10 of
Master Catalogue

Products: Glenair, established in 1956, has both underwater cable and connector capability, and manufactures a range of standard and custom cables and connectors. It produces metal shell, high density and hermetic, plastic and rubber molded connectors. It also markets a line of bulkhead penetrators, and a variety of accompanying accessories.

Users include: Westinghouse Oceanic Division, Annapolis, MD 21404.

Johns Hopkins University, Applied Physics Laboratory,
Laurel, MD 20810.

EDO Western, Raytheon, Gould Chesapeake, Naval Ship
R&D Center.

Present connector research: Glenair is developing high pressure (10,000 psi) hermetic connectors with high density contact arrangements (i.e., 128 contacts in size 24 connector). They are also developing a plastic high density 2,500 psi connector which will reduce connector costs on underwater instrument packages.

Information contributed by: Allan R. Froome, Division Mgr.,
Glenair (3-23-76).

12. GOULD, INC.
Advanced Development Division
18901 Euclid Avenue
Cleveland, OH 44117
(216)-486-8300 (for information and bids)

See SECTION 11 of
Master Catalogue

Products: Gould produces a variety of underwater products, including hydrophones, markers, sonar and transponders. It markets a standard CX line of metal shell bulkhead and in-line connectors and cable assemblies.

Users include: Naval Underwater Systems Center, Newport, RI 02840: Gould connectors used for hydrophone systems, from 1970 to 1976.

Naval Surface Weapons Center, White Oak, Silver Spring, MD 20910: Gould connectors used for hydrophone systems, from 1971 to 1976.

Information contributed by: Kenneth S. West, Sr. Transducer
Engineer, Gould (3-12-76).

13. HEXCEL CORPORATION
20701 Nordhoff Street
Chatsworth, CA 91311
(213)-882-3022 (for information and bids)

See SECTION 12 of
Master Catalogue

Products: Incorporated in 1948, Hexcel has a variety of products, including specialty resins and its well-known Hotsplicer field-molding splicing system for electrical transmission and distribution cable. Hexcel markets a wide selection of field cable splicing units and potting compounds.

14. ITT CANNON ELECTRIC
2801 Airplane
Phoenix, AZ 85034
(602)-275-4792 (for information and bids)

See SECTION 13 of
Master Catalogue

ITT CANNON ELECTRIC
4 Cannon Court
Whitby, Ontario
Canada
(416)-668-8881 (for information and bids)

ITT CABLE-HYDROSPACE
P.O. Box 81446
San Diego, CA 92138
(714)-474-6341 (for information and bids)

ITT CANNON ELECTRIC
666 E. Dyer Road
Santa Ana, CA 92702
(714)-557-4700 (for information and bids)

Products: ITT Cannon produces interconnection devices, both surface and subsurface, and has developed an extensive variety of metal shell underwater connectors and a full range of accessories. It manufactures cable, as well, and has the capability to supply both standard and custom cable and connector assemblies. Among its numerous underwater connector lines are the metal shell MIL-C-24217, MIL-C-22249, and MIL-C-22539 assemblies (ITT Cannon, CA, AZ). ITT (Canada) markets a line of brass shelled underwater connectors; ITT Cannon (CA, AZ) produces standard lines of metal shell hermetic connectors, downhole connectors, blowout preventers, electro-hydraulic connectors, high density geophysical connectors and seismic streamer connectors, and bulkhead penetrators. ITT Cable-HydroSpace produces integrated cable and connector systems, Kelvar terminations, and fiber-optic underwater data transmission systems.

Users include: Supply Officer, Naval Underwater Systems;
(401)-841-3684: ITT Cannon connectors used for underwater instrumentation, from 1973 to 1975.

Present connector research: Off shore drilling applications, fiber optics.

Information contributed by: B.M. Vandermark, ITT Cannon
at Phoenix (2-26-76).

15. JOY MANUFACTURING CO.
Electrical Products Department
338 So. Broadway
New Philadelphia, OH 44663
(216)-343-3351 (for information and bids)

See SECTION 14 of
Master Catalogue

Products: Joy markets a line of rubber molded in-line single conductor connectors (X8372 series) which is available in a metal bulkhead feedthru. The same series comes in a field attachable application.

16. KEMLON PRODUCTS AND DEVELOPMENT CO.,
An Affiliate of Keystone Engineering Co.
P.O. Box 14666
Houston, TX 77021
(713)-747-5020 (for information and bids)

See SECTION 15 of
Master Catalogue

Products: Kemlon produces a variety of metal shell, epoxy sealed, bulkhead and in-line connectors. It also markets rubber molded assemblies. It specializes in glass-sealed single contact arrangements, but produces a number of multiple contact hermetic connectors as well. It also markets Teflon connectors, splicing boots, triaxial connectors and a number of unusual button connectors and multiple feedthrus.

Users include: Several major oil well service companies, Lawrence Radiation, and unspecified departments of the U.S. Navy. Kemlon will supply names of individuals on specific letter request only.

Present connector research: Continuing research is aimed at increasing life and servicability of underwater connectors.

Information contributed by: Richard Neese, Marketing Manager, Keystone Engineering Co. (3-15-76).

17. KINTEC, INC.
9547 Cozycroft Avenue
Chatsworth, CA 91311
(213)-998-8822 (for information and bids)

See SECTION 16 of
Master Catalogue

Products: Kintec, established in 1963, markets a broad range of underwater connectors, penetrators and connector accessories. It manufactures both standard and custom connector assemblies, in metals, plastics and rubber compounds. Among its standard lines are two metal shell series, one of them (MS Series) conforming in interface design to the MIL-C-24217 design. Additional standard lines are offered in both plastics and rubbers, with a wide variety of contact arrangements. Kintec markets its HS4 series in an underwater mateable and offers a pressure-balanced oil-filled assembly in its LP series. One of Kintec's specialties is the field-installable assembly and most of its standard series come with this option.

Users include: Naval Coastal Systems Laboratory, Panama City, FL 32401; (904)-234-4011: Kintec underwater electrical connectors used on LOSS Program (Large Objects Salvage System) for all pontoon and vehicle terminations required, from 1972 through 1976. No failures to date.

Kennecott Explorations, Inc., Ocean Operations Div., 10306 Roselle St., San Diego, CA 92121; (714)-453-3751: Kintec connectors used on Prototype Mining Vehicle to total of 400 connectors and assemblies (\$300,000.00 contract) for 3 months, from July 1974 to October 1974. No failures.

Naval Civil Engineering Lab., Port Hueneme, CA 93043; (805)-982-4711: Kintec connectors used on DSRV battery terminations.

International Hydrodynamics Co., Ltd., P.O. Box 1059 Station A, Vancouver, B.C., Canada V6C 2P1; (604)-929-2391: Kintec connectors used on underwater vehicles, from 1970 to 1976.

Naval Undersea Center, So. Rosecrans Pt. Loma, San Diego, CA 92132; (714)-225-7201: Various Kintec connectors used.

Naval Weapons Center, China Lake, CA 93555; (714)-939-2088: Kintec connectors used on swimmer delivery vehicles.

Taylor Diving and Salvage Co., 795 Engineer Rd., Belle Chasse, LA 70037; (504)-394-6000: Kintec connectors used for dive systems.

Naval Research Lab., P.O. Box 8337, Orlando FL 32806:
Kintec connectors used for transducer terminations.

Northrop-Ventura, 1515 Rancho Conejo Blvd., Newbury
Park, CA 91320; (805)-498-3131: Kintec connectors
used for torpedo targets.

Perry Submarine Builders, 100 E. 17th St., Riviera
Beach, FL 33404; (305)-842-5261: Kintec connectors
used on submarines, dive chambers and instruments.

Naval Underwater Systems Center, New London, CT 06320:
Kintec connectors used on towed arrays.

Present connector research: Prototypes of each of the follow-
ing are currently in field service: (1) continuing
efforts to expand line of field installable connectors
allowing field installation without molding or encap-
sulation; (2) continuing efforts to modify and improve
MIL-C-24217 connector design, including the adapta-
tion of Kintec water blocked contact inserts and modi-
fications allowing field installation without molding;
(3) sub-sea remotely controlled underwater make and
break for offshore platform electro-hydraulic control
systems; (4) electro-mechanical underwater connectors
with built-in test chamber for field test and evaluation;
(5) sub-sea connectors with helium block capability.

Information contributed by: Neil B. Karliskind, Kintec (6-17-76)

18. MARK PRODUCTS, INC.
10507 Kinghurst Drive
Houston, TX 77072
(713)-498-0600 (for information and bids)

See SECTION 17 of
Master Catalogue

Products: Mark Products produces an Amphib series of plastic
three and four contact connectors which are field re-
pairable and designed for underwater pressures of 50
and 500 psi.

19. MASSA DIVISION, DYNAMICS CORP. OF AMERICA
280 Lincoln Street
Hingham, MA 02043
(617)-749-4800 (for information and bids)

Products: Underwater connectors and cable assemblies--no catalogue or background information available at time of survey.

20. MECCA TELEDYNE
P.O. Box 36393
Houston, TX 77081
(713)-772-2811 (for information and bids)

Products: Underwater connectors and cable assemblies--no catalogue or background information available at time of survey.

21. D.G. O'BRIEN, INC.
498 Cochituate Road
Framingham, MA 01701
(617)-872-6596 (for information and bids)

See SECTION 18 of
Master Catalogue

Products: D.G. O'Brien markets an extensive line of standard and custom metal shell connectors and cable assemblies for underwater applications. It manufactures MIL-C-24217 and MIL-C-22539 connectors, a line of miniature metal shell connectors (103, 104 series), a series of miniature coaxial bulkhead and in-line connectors (110 series), a low cost compression-glass-sealed series (124 series), and bulkhead penetrators. D.G. O'Brien connectors come in a wide variety of in-line and bulkhead mounting applications. Pin contacts molding materials, crimping, insertion and extraction tools all follow MIL-specifications. In addition, a 117, 126, 127 series of glass sealed connectors are designed for use with D.G. O'Brien fluid-filled underwater cable assemblies, which allow for termination and assembly modification in the field.

22. PELCON, LIMITED
P.O. Box 8143, Station A
St. John's, Newfoundland A1B 3M9
Canada
(709)-386-2136 (for information and bids)

See SECTION 19 of
Master Catalogue

Marketed in USA by:
STEWART AND STEVENSON OILTOOLS, INC.
P.O. Box 1473
Houston, TX 77001
(713)-861-2101 (for information and bids)

Products: Pelcon specializes in inductive coupler applications, furnishing underwater make and break capability for electrical applications. It markets several series of inductive couplers of varying sizes and capabilities which terminate in a conventional manner but interface without contacts. These are available in a number of different mounting and mating arrangements and may be used for intercom systems, data transmission, low underwater d.c. power for transducers and electronics packages.

23. PREFORMED LINE PRODUCTS CO.
Marine Systems Division
P.O. Box 91129
Cleveland, OH 44101
(216)-461-5200 (for information and bids)

See SECTION 20 of
Master Catalogue

Products: Standard cable hardware designed to mechanically terminate electro-mechanical cables and wire rope. The products grip the cable by use of helical wire rods which distribute the radial holding force over a large area thus avoiding stress concentrations. The conductor elements of the cable can then be terminated with a variety of underwater electrical connectors in a pigtail fashion.

Preformed Line also fabricates special cable assemblies to customer requirements, using a variety of cables and electrical connectors supplied by cable and connector manufacturers, and its own special designs for mechanical termination, sealing, and bending strain relief. Assemblies are tested before shipment, including tensile proof loading, hydrostatic pressure testing, and electrical measurements.

Preformed Line also maintains a cable and termination test facility which is used for testing its own products before shipment (acceptance testing), new product development, and contract testing. They have conducted test programs under contract to the U.S. government as well as numerous cable and hardware manufacturers.

Users include: Naval Underwater Systems Center, New London, CT; (203)-442-0771: Preformed Line Termination used for AN/BQQ-5 fixed tow system; for submarine sonar system; for sub-to-tow cable; for tow cable to sonar array, 1973 to present.

Gould, Inc., Chesapeake Inst. Div., Shadyside, MD; (301)-867-2151: Preformed Line terminations used for Stass submarine sonar system; for tow cable to sonar array, 1974 to present.

Present connector research: Preformed Line is now in the development testing stage for a concentric electro-mechanical connector which utilizes a MIL-C-24217 connector and allows mechanical and electrical connections to be made together at the same time. This assembly will also be intermateable with a standard MIL-C-24217 assembly. Preformed Line is also developing a slip-on bending strain relief device for the same assembly.

Information contributed by: Robert A. Patterson, Marketing Manager, Preformed Line Products (6-1-76).

24. SOURIAU ET CIE
9/13 rue Gallieni
92103-Boulogne Billancourt
France
604-20-00

See SECTION 21 of
Master Catalogue

Marketed in USA by
INTEROCEAN SYSTEMS, INC.
3510 Kurtz Street
San Diego, CA 92110
(714)-299-4500 (for information and bids)

Products: Souriau is a large French connector company with its main plant situated in Boulogne. It markets in the USA through InterOcean Systems, Inc. of San Diego. Its connector products include a variety of underwater metal shell connectors, underwater mateable connectors, and an extensive selection of pin configurations, mountings, pottings and accessories.

Users include: Compagnie Francaise Des Petrols, 39 Aui A. Citroen, 75015 Paris, France; (1)-578-33-33: Souriau underwater connectors used for various ships, including Le Pelican, Le Petrel, Le Pelerin, from 1973 to present.

Comex, Traverse de la Jarre, 13009 Marseille, France; (91)-40-11-70: Souriau connectors used for the Comex Rescue Submarine, from 1969 to present.

Present Connector Research: Souriau is in final stages of developing its 8810 connector, an underwater mateable coaxial type connector, which it expects to market in 1977. It is also completing the development of a special connector endbell which will ensure watertightness in the event that the outside sleeve of a given connector is damaged. This will be marketed in late 1976.

Information contributed by: M. Guilloteau, Technical Manager, Souriau (3-16-76).

25. VECTOR CABLE COMPANY,
A Division of Schlumberger
Technology Corp.
555 Industrial Road
Sugar Land, TX 77478
(713)-494-9196 (for information and bids)

See SECTION 22 of
Master Catalogue

Products: Vector is an integrated cable and connector company, specializing in both standard and custom underwater electro-mechanical applications. It has one of the more extensive off-the-shelf connector selections and maintains a field crew to assist in difficult field applications and to trouble-shoot. Vector's connector products include a variety of metal shell, glass epoxy and rubber molded underwater connectors, marketed under the trade name of 'Marsh and

Marine." It also markets bulkhead penetrators, hermetic connectors, combined electro-mechanical terminations, field-installable connectors, cable splices and takeouts, and a full range of connector accessories, mounting and potting options. It has an extensive and highly innovative R&D program and has recently developed a number of new bonding techniques.

Users include: Brown and Root, Houston, TX: Marsh and Marine underwater connectors used on B.P. 40's Project for instrumentation of a large offshore oil production platform with more than 3,000 separate cable and connector assemblies, from 1974 to present.

Lockheed Missiles and Space Co., Sunnyvale, CA: Marsh and Marine underwater pressure hull penetrators and cable assemblies used on Deep Quest Manned Submersible Project, from 1968 to present.

Present connector research: (1) Development of underwater mateable connector systems for power circuits and multiple signal circuits for diver, manipulator, and remote makeup; (2) Fluid-filled pressure-compensated field-installable connectors for power and signal circuitry, including underwater television; (3) Tether cables and connector-cable harnesses for free swimming underwater vehicles; (4) Procedures and techniques for installing all types of connectors on different types of cables to preserve the electrical integrity of all circuits in the system on jacketed or free flooded cables.

Information contributed by: R.E. Tyler, Manager, Connector Product Engineering, Vector (3-31-76).

26. VIKING INDUSTRIES, INC.
Special Products Division
9324 Topanga Canyon Blvd.
Chatsworth, CA 91311
(213)-882-6275 (for information and bids)

See SECTION 23 of
Master Catalogue

Products: Viking produces both standard and custom underwater electro-mechanical cable terminations. It has complete in-house capability for tooling, manufacturing, testing and cabling of its connectors. Although Viking produces a variety of special custom connector

assemblies, it specializes in the production of standard connectors to MIL-C-24217, MIL-C-22249 and MIL-C-22539 specifications. In addition, it markets a standard line of Pisces underwater mateables and will perform electrical and environmental testing to customer and/or military specifications. Viking also markets a line of pressure-balance oil-filled assemblies.

Users include: U.S. Navy, NSC, San Diego, CA; Mare Island Naval Shipyard, CA; Naval Undersea Center, Hawaii: for various applications.

Ametek-Straza, 790 Greenfield Dr., El Cajon, CA; (714)-442-3451: Viking connectors used for sonar cable assemblies, from 1970 to present.

Present connector research: (1) Viking is developing a number of expanded arrangements for its Pisces underwater mateable connectors; (2) Continued emphasis is being placed on developing capabilities and techniques to meet special customer requirements; (3) Viking is also developing a geophysical streamer connector with up to 260 contacts.

Information contributed by: Dick Skelton, Product Manager, Viking (4-30-76).

5.3 Custom Underwater Connector Manufacturers

Although many of the following organizations do not market standard lines of underwater connectors and, hence, do not have catalogues, they represent a group with substantial research experience in underwater connector and penetrator design. Many of them have expertise and technologies which have applications in connector design; others are nonprofit organizations which are making contributions to connector technology.

1. AMPHENOL SAMS DIVISION,
Bunker-Ramo Corp.
9201 Independence Avenue
Chatsworth, California 91311
(213)-341-0710 (for information and bids)

Products: Amphenol markets a range of standard surface connectors. It produces special underwater electrical connectors for highly engineered cable systems and accepts special connector design orders.

2. APPLIED PHYSICS LABORATORY,
University of Washington
1013 N.E. 40th Street
Seattle, WA 98195
(206)-543-1363 (for information and bids)

Applications: Design and install cable sealing systems for general underwater structures and electronics housings. Specialize in use of interference seals and seal assemblies for various deep ocean applications, as well as for cable splicing.

3. THE BENDIX CORPORATION
Environmental Science Division
1400 Taylor Avenue
Baltimore, MD 21204
(301)-825-5200 (for information and bids)

Products: Bendix (MD) markets environmental equipment, offering a complete line of meteorological, health and safety equipment, as well as oceanographic equipment. Normally, Bendix will only produce support equipment for their own oceanographic lines; however, technology is available to consider special connector order work.

Information contributed by: T.E. Lassiter, Jr., Service-Sales Manager, Bendix (2-18-76).

4. CELMARK ENGINEERING, INC.
9822 Independence Avenue
Chatsworth, CA 91311
(213)-998-0244 (for information and bids)

Products: Celmark specializes in custom development and design of underwater electrical connectors, penetrators and cable assemblies. They manufacture connectors from numerous available metals, plastics and rubber compounds, and have supplied MIL-C-24217 and MIL-C-22539 connectors to various customers.

Users include: Lockheed Petroleum, Vancouver; Lockheed, Sunnyvale, CA; Lockheed, San Diego: Celmark penetrators and plugs used for various underwater applications, 1975 to present.

NAVSEC, Prince George Center, Washington, D.C.:
Celmark connectors used, from 1975 to present.

USN, NUC, Hawaii: Celmark participating in development of 13,500-psi capability, high voltage coaxial connector to be used in ROUS program.

NCEL, Port Hueneme, CA: Celmark participating in development of battery plugs and harnesses for DSRV.

Present connector research: Celmark is working on the development of an underwater mateable connector and on a number of new coupling techniques for connectors, including a quick disconnect design. Celmark has also been working on the development of a new technique for bonding polyethylene to stainless steel and aluminum and is now in the testing stage for this technique.

Information contributed by: Tony Gloacz, Celmark (6-22-76).

5. CERAMASEAL, INC.
P.O. Box 25
New Levanon Center, NY 12126
(518)-794-7800 (for information and bids)

Products: Ceramaseal is a manufacturer of high alumina ceramic terminals, bushings and connectors of all types for both vacuum and high pressure requirements. Ceramaseal has not designed or supplied underwater electrical connectors to date, but it has supplied ceramic-metal assemblies which have been used in final assemblies of some customers for underwater applications.

Information contributed by: Gene D. Sawin, Sales Manager, Ceramaseal (3-22-76).

6. CIVIL ENGINEERING LABORATORY, U.S.N.
Construction Systems Division
Ocean Engineering Department
Port Hueneme, CA 93403
(805)-982-5423 (for information and bids)

Applications: CEL has developed several special cable termination systems, among them a series of underwater mateable cable terminations for such applications as power distribution to seafloor production systems, power and signal umbilicals, downhole electrical connections and emergency quick-release systems. See final entry of Master Catalogue for details of CEL underwater mateable. CEL has also developed a method for splicing cable underwater and is presently working on developing a longer life for such underwater splices and on developing the capability for splicing SD cable remotely in deep ocean environments.

Information contributed by: Jeffrey V. Wilson, Mechanical Engineer, CEL (5-7-76).

7. DEEP OIL TECHNOLOGY, INC.
1280 Windham Avenue
Long Beach, CA 90802
(213)-436-7208 (for information and bids)

Products: DOT manufactures a number of underwater mateable connectors with high voltage and current capacities, and which are used both for underwater instrumentation

packages and for subsurface hydro pumps. It is presently developing a new high-density series of underwater mateables.

8. GENERAL OCEANICS, INC.
5535 N.W. 7th Avenue
Miami, FL 33127
(305)-754-6658 (for information and bids)

Products: Various instrumentation and oceanographic equipment. Will supply connectors for certain applications.

9. GULTON INDUSTRIES, INC.
Connector Division
1644 Whittier Avenue
Costa Mesa, CA 92627
(714)-642-2400 (for information and bids)

Products: Underwater connectors and cable assemblies--no catalogue or background information available at time of survey.

10. JETTRON PRODUCTS, INC.
P.O. Box 337
East Hanover, NJ 07936
(201)-887-0571 (for information and bids)

Products: Manufactures custom connectors and cable assemblies.

11. NAVAL TORPEDO STATION
Research and Engineering Department
Keyport, WA 98345
(206)-396-4543 (for information and bids)

Applications: NTS has broad experience in the installation of underwater cable termination devices. It also has experience in the use of interference cable seal assemblies for various applications.

12. NAVAL UNDERWATER SYSTEMS CENTER
New London, CT 06320
(203)-442-0771 (for information and bids)

Applications: NUSC has varied and extensive experience in the use of both commercial and special design connectors, cable assemblies and penetrators. They have recently done their own special design work on small diameter electro-mechanical coupling devices, and on Kelvar type cable terminations.

13. ARTHUR L. NELSON AND CO.
P.O. Box 9745
San Diego, CA 92109
(714)-274-2115 (for information and bids)

Products: Arthur Nelson pioneered work on underwater mateable connectors and did much of the original work on field termination techniques which led to the development of the Hotsplicer process. His present company specializes in design and development of special underwater cable termination processes, and in custom manufacture of connectors.

Users include: Scripps Inst. of Oceanography, La Jolla,
CA: Nelson connectors used for unspecified applications.

Hexcel Corp., 20701 Nordhoff St., Chatsworth, CA 91311:
Nelson connectors used for unspecified applications.

Present connector research: Working on a high-voltage, high-current underwater mateable line of connectors.

Information contributed by: Arthur Nelson, Owner (4-1-76).

14. ROWE INDUSTRIES
6225 Benore Road
Toledo, OH 43612
(419)-729-9761 (for information and bids)

Products: Rowe is actively engaged in design, development and manufacture of connectors and interconnection systems used in underwater and geophysical applications. Rowe has supplied numerous major companies, including the U.S. Government, with connectors of all types used in underwater and other severe environments.

Rowe employs 90 people, including an engineering staff, a quality-control department with a system conforming to MIL-Q-9858A, and complete in-house tool and die and machining operations. Rowe has a tape controlled random access circuit analyzer permitting rapid testing of electrical parameters during or following hydrostatic testing. Available floor space is 55,000 feet, and sales are \$3 million per year.

Users include: Borg-Warner: Rowe connectors used for underwater equipment associated with offshore oil well drilling industry, 1975 to present.

U.S. Navy: Rowe connectors used on various torpedo programs, including the Mk 48, as well as with the cruise missile program and other classified projects related to the Trident system, from 1970 to present.

Present connector research: Rowe is currently designing and developing umbilical connectors and cable assemblies involving the termination of high tensile strength members used in underwater applications. They are also working on a number of classified projects involving high pressure and temperature hermetically sealed connectors for underwater applications.

Information contributed by: David. L. Mang, Western Regional Sales Manager, Rowe (2-17-76).

15. SIMPLEX WIRE AND CABLE CO.
P.O. Box 479
Portsmouth, NH 03801
(603)-436-6100 (for information and bids)

Products: Simplex is a manufacturer of undersea cables for power and communication, and of armored flexible polyethylene pipe. They have a staff with engineers who have specific experience in the design and production of undersea connectors and who undertake custom connector design and production. Annual sales are \$18 to \$20 million, with approximately 300 employees.

Users include: NUSC, New London, CT: Simplex connectors used to connect hydrophones to cables and arrays, from 1965 to present.

G.E. Project, G.E. Co. HMES, Syracuse, NY: Simplex breakouts used for instrumentation, currently.

Information contributed by: H.H. Hauser, Manager, Marketing Administration, Simplex (2-10-76).

16. SOUTHWEST RESEARCH INSTITUTE
8500 Culebra Road
P.O. Box 28510
San Antonio, TX 78284
(512)-684-5111 (for information and bids)

Applications: The Southwest Research Institute is a not-for-profit research and development organization with extensive design experience in underwater electrical applications. SWRI designs and fabricates only special electrical connectors. It has patents on a high power underwater connector and on an underwater mateable connector, and has an ongoing program on subsea power and connector development.

Users include: NCEL, Port Hueneme, CA: Development of connectors to provide power for Sea Con and to provide developmental data.

Exxon, USA: development of a special connector application to provide 5,000 hp at 3,000 feet.

Information contributed by: Edward M. Briggs, Manager, Ocean Engineering, SWRI (2-11-76).

17. SUPERIOR SWITCHBOARD AND DEVICES

P.O. Box 590

Canton, OH 44706

(216)-452-4681 (for information and bids)

Products: Primarily a manufacturer of wire rope fittings under tradename of Electroline. Supply special swivels and connectors for deep ocean applications, on special order.

Information contributed by: Ray W. Muse, Supervisor of Sales and Service, Superior (3-1-76).

18. TIMES WIRE AND CABLE CO.

358 Hall Avenue

Wallingford, CT 06492

(203)-265-2361 (for information and bids)

Products: Primarily a cable manufacturer. However, Times has some manufacturing experience in special cable assemblies.

Section 6

TABLE OF CONTENTS

<u>Section</u>	<u>Title</u>	<u>Page</u>
6.1	Failure Analysis and Prevention	6-1
6.1.1	Introduction	6-1
6.1.2	Performance/Failure Analyses: Some Results and Recommendations	6-3
6.1.3	Failure Mode Analysis	6-8
6.1.4	Quality Assurance: Quality Control and Certification Guidelines	6-24
6.1.5	Performance/Failure Analysis Plan	6-39
6.1.6	Directions for Future Research	6-43
6.1.7	References	6-44
6.2	Pertinent Military Specifications	6-45
6.2.1	For Electrical Connectors	6-45
6.2.2	For Electrical Cables	6-46
6.2.3	For Connector Materials	6-46
6.2.4	U.S. Government Plating Specifications	6-47
6.2.5	Connector Test Specifications	6-48
6.3	Bibliographies on Connector Technology and Related Subjects	6-49
6.3.1	Connector Design	6-49
6.3.2	Seal Design	6-54
6.3.3	Corrosion and Environment	6-56
6.3.4	Potting Compounds	6-58
6.3.5	Insulation Materials	6-60
6.3.6	Adhesives	6-61
6.3.7	Quality Control	6-62

Section 6

LIST OF FIGURES

<u>Figure</u>	<u>Title</u>	<u>Page</u>
6-1	Organization of Connector Development Plan	6-2
6-2	Evidence of Connector Failure by Leaking. Five out of six connector/penetrators produced leak deposits on the inside face of the junction box bulkhead.	6-7
6-3	Possible Leak Paths into a Morrison-Type Sealed Connector	6-23
6-4	Components of a Commercial Connector	6-25
6-5	Possible Leak Paths of a Commercial Connector	6-26
6-6	Mated Connector Test Circuit	6-32

LIST OF TABLES

<u>Table</u>	<u>Title</u>	<u>Page</u>
6-1	Documented Failures	6-5
6-2	Failure Modes	6-10
6-3	Possible Failure Modes and Effects--Electrical Connector Plug	6-17
6-4	Possible Failure Modes and Effects--Electrical Connector Receptacle	6-18
6-5	Possible Failure Modes and Effects--Receptacle in Hull	6-19
6-6	Possible Failure Modes and Effects--Junction Box Hull	6-20
6-7	Design Verification Test Sequence for Connectors	6-29
6-8	Hydrostatic Pressure Test Schedule	6-32

LIST OF TABLES, CONT.

<u>Table</u>	<u>Title</u>	<u>Page</u>
6-9	Preproduction Qualification Test Sequence for Connectors	6-35
6-10	Quality Conformance Test Sequence for Connectors and Accessories	6-36

Section 6

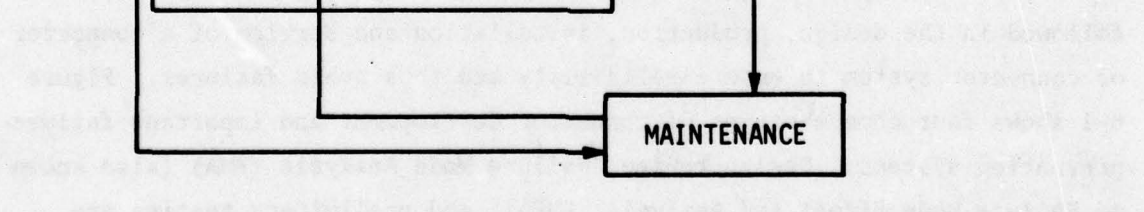
REFERENCE SECTION

6.1 Failure Analysis and Prevention

6.1.1 INTRODUCTION

This section addresses the problem of underwater electrical connector failure and how to prevent it. The term "failure" as used here means the cessation of function, or usefulness, of a submerged conductor because of electrical, chemical, metallurgical, or mechanical problems. The primary method of documenting success or failure in a system is called performance/failure analysis. One function of failure analysis is to investigate failures to determine their causes and to identify design features or production processes that should be improved. Common electrical failures include shorts and discontinuities. Metallurgical and electrochemical problems include faulty material composition and corrosion damage to connectors and supporting structures. Mechanical problems refer to excessive strains or fracture during assembly, maintenance or service operation. Leakage may result from deficiencies in design, errors in selection of materials, imperfections in the materials themselves, errors in manufacture and installation that are not detected or corrected by quality control, and from unexpected service conditions.

The term "prevention" refers to systematic procedures that must be followed in the design, production, installation and service of a connector or connector system to ensure reliability and thus avoid failures. Figure 6-1 shows four common stages of connector development and important failure prevention systems. Design review, Failure Mode Analysis (FMA) (also known as Failure Mode Effect and Analysis, FMEA), and preliminary testing are performed early in the development of a connector or connector system to detect inadequacies in the design. Once a design is approved, quality control is exercised over the procurement of parts and materials and over subsequent processing to detect and prevent deficiencies in manufacturing,



Ideally, if the procedures described above are used over an extended period of time, quantitative data on the strengths and weaknesses of connectors and connector systems will be collected. This information can then be applied in logic network methods such as FMEA (see Reference 1), system safety analysis (see Reference 2), or fault tree analysis (see References 3 and 4) to provide quantitative predictions of connector reliability. Moreover, "weak links" in a connector design can be isolated precisely and strengthened in future designs. Ultimately, failure prevention methods should lead to optimum design and meaningful certification requirements that maximize the reliability of connectors and connector systems for minimum cost.

6.1.2 PERFORMANCE/FAILURE ANALYSES: SOME RESULTS AND RECOMMENDATIONS

A large part of the following information was extracted from failure analyses performed by the Department of Research and Engineering and the Department of Quality Engineering and Evaluation at the Naval Torpedo Station (NTS), Keyport, Washington.* Additional information in this section comes from the experience of scientists and engineers at the Applied Physics Laboratory.

6.1.2.1 Failure Analyses of Commercial Connectors with Molded Boots.

Since mid-1974 Performance/Failure Analyses have been made on several 3-D acoustic arrays which were recovered after service at either the Nanoose range off Vancouver Island, B.C., or the Dabob Bay range in Washington State. The results may be summarized as follows:

1. The main failure mode appeared to be short circuits caused by seawater leaking through corrosion paths around O-ring seals although some array failures resulted from corrosion of connectors and machined components composed of AISI 1213 steel (a free-machining steel with small quantities of sulphur and phosphorous); AISI 1213 steel exhibits poor corrosion resistance in seawater due to the presence of manganese sulfide particles.

* These analyses were collected and summarized in a report entitled "Failure of Underwater Connectors" by Mr. Ted Austin of NTS as part of a course in mechanical engineering at the University of Washington on marine corrosion in 1976.

2. According to the manufacturer, the connectors were not designed to operate in the manner in which they were used; that is, the connectors were designed to resist pressure not from the end that was exposed to pressure, but from the opposite end.
3. The clearances for some O-ring piston seals were out of tolerance; that is, allowable clearance on the diameter was 0.006 inch whereas the actual clearance was as much as 0.014 inch. Therefore, the sealing capacity and resistance of the seal were reduced.
4. The time it takes for leaks to develop past O-ring seals due to corrosion apparently increases linearly with increasing contact area between the O-ring and the groove or metal surface.
5. O-ring surfaces that were heavily lubricated apparently were more resistant to corrosion damage.
6. No leakage occurred around properly installed Morrison seal elements. The weak link in the connectors utilizing Morrison seals apparently was the piston-type O-ring seal.
7. Certain lots of Morrison seal material were found to be conductive when compressed. It is postulated that compression stresses force carbon particles closer so that low electrical resistance paths are created across the seal.
8. The polyethylene-jacketed cables that were recovered and examined on or about March 1975 had performed satisfactorily for more than 9 years.
9. Apparently seawater permeated a neoprene cable jacket.
10. Cathodic protection with sacrificial zinc anodes apparently was effective in reducing connector failure by corrosion.
11. Zinc anodes that are contaminated with iron do not perform satisfactorily. Zinc anodes that meet Mil-A-18001 are recommended.

12. The primer paint coating on some connectors did not perform satisfactorily. Nonuniform primer color indicated that improper mixing procedures were used and lack of complete coverage indicated improper application. Some connector housings were not thoroughly sandblasted prior to primer application.
13. Some connector failure occurred because of leakage of seawater through the interface between the boot and the cable jacket.
14. Out-dated, two-part urethane encapsulating material apparently has inadequate strength and bonding properties.

Table 6-1 shows the most common failures, their frequency of occurrence and the age at which failure occurred. Failure of the bond between the boot and the connector sleeves occurred the most frequently. The second most frequent cause of failure was leakage past corroded O-ring seal surfaces.

Table 6-1. Documented Failures

CAUSE OF FAILURE	FREQUENCY OF OCCURRENCE	AGE AT RECOVERY (months)
Bond failure of polyurethane boot-to connector sleeves	6	2, 8, 13, 28, 36, 39
Failure caused by seawater leakage past corroded sealing surfaces of the connector-to-bulkhead O-ring	5	28, 36, 36, 39, 69
Zinc anodes did not function	4	2, 8, 13, 8
Bond failure of polyurethane boot-to cable jacket	3	2, 8, 13
Zinc anodes did not function due to high iron content	2	36, 69

6.1.2.2 Visual Evidence of Leaking. The presence of corrosion products can identify leaking connectors. In some cases, the leak path can be traced by following the trail of corrosion products. Figure 6-2 shows the inside face of a junction box bulkhead recovered in 1976. The location of corrosion products indicates that leakage occurred in five out of six connectors that were mated to the outside of the bulkhead. (One of the seven connector holes was filled with a dummy insert.) Inspection of the bulkhead in Figure 6-2 and the connectors and connector assemblies revealed that the cause of failure was leakage due to corrosion.

A brief description and history of the array are shown below:

Type:	3-D acoustic array
Location:	NanOOSE Range, Vancouver Island, British Columbia
Depth:	1300 ft (approximately)
Duration:	4 years (March 1972 to May 1976)
Indications of Failure:	C-phone output decreased in April 1972 C-phone output failed in February 1976 After recovery C-phone resistance between center and shield equaled 500 ohms
Design:	Commercial connectors with O-ring seals and molded boots

Investigation of the recovered junction box revealed the following:

1. Approximately 1/2 inch of water was standing in the housing.
2. The external joint between the receptacles and the bulkhead was not potted over.
3. Leaks occurred under receptacle-to-bulkhead O-rings in five of the connectors.
4. The bulkhead-to-housing O-rings showed no evidence of leaking.
5. In a few connectors the molded polyurethane boot between the cable and the connector shell exhibited poor adhesion to the metal connector shell, as evidenced by corrosion products and water at the interface between the connector shell and the boot.



Figure 6-2. Evidence of Connector Failure by Leaking. Five out of six connector/penetrators produced leak deposits on the inside face of the junction box bulkhead.

6.1.2.3 Recommendations for Improving Connector and Seal Performance.

The foregoing investigations indicate that failures of connectors and connector systems can result from single or multiple errors at any or all phases of connector development from initial design to final installation. Therefore, to improve connector performance and reliability, proper quality control procedures must be adhered to from the early design stage through fabrication and installation. Specific actions that hold promise of improving connector performance are listed below. Some of these items are currently being tested, and some are hypotheses based on performance analysis results.

1. Use Morrison seals instead of O-rings, and carefully test seal materials.
2. Where O-rings are necessary, use primary and secondary (backup) O-rings.

3. Pack the O-ring grooves and clearance volumes with O-ring lubricant or other heavy corrosion-resistant grease.
4. Use special care when preparing and painting all metal surfaces exposed to seawater.
5. Locate sacrificial anodes to protect seal-to-water interfaces. (Tests should be performed to determine if hydrogen production on cathode areas (unpainted seal surfaces) can displace O-ring lubricant.)
6. Locate Morrison sealing elements around cables and conductors to isolate each possible leak path (hosing) along the cable. In the case of D.G. O'Brien connectors, the Morrison sealing elements can be located around the cable inside the potting material for the boot.
7. Use only new potting material for the potted boots and prepare the connector sleeve for good adhesion by the best mechanical and chemical cleaning methods.
8. Use corrosion-resistant connector materials such as plastic, copper-nickel alloys, or painted C1010, C1030, C1018 or C1026 steel.
9. Accurately control dimensions of all O-ring grooves and joints.
10. Use strict material control procedures.

6.1.3 FAILURE MODE ANALYSIS

Failure Mode Analysis (FMA) takes place primarily in the early stages of connector design and development. The major objectives of the FMA are to identify potential failure modes in a connector or connector system design, and to predict the effect of each potential failure on the system. As a result, latent design and production deficiencies can be corrected comparatively easily and inexpensively before the manufacture of actual production models. Although FMA is considered to be a design evaluation technique, it does interrelate with activities mainly concerned with hardware evaluation.

This section outlines two FMA procedures, one qualitative and the other quantitative. In addition, the section provides the following:

- 1) a table listing failure modes and possible causes for connector parts;
- 2) four tables listing failure modes and possible effects organized around function of connector parts; and
- 3) figures illustrating possible leak paths in selected connectors.

6.1.3.1 FMA Procedures. At the present time, the potential effectiveness of the FMA is seriously hampered by a lack of quantitative data on the probability of failure by any specific failure mode. Although underwater connector failures have occurred in deep water, sufficient information on the active failure modes is not available. Because of the lack of sufficient quantitative data at this time, a qualitative method must be employed. The procedure for a qualitative method is outlined below.

Qualitative FMA Procedure Outline

1. Make a logic block diagram of the connector system.
2. Perform a functional boundary analysis to indicate the function and the functional boundary of each component part and operation.
3. Identify the possible failure modes of each part, process and operation. (See Table 6-2, "Failure Modes," on p. 6-10 to reference types of failure modes and their sources.)
4. Identify the possible effects of the failure modes and backup features in the design. (For this purpose, reference Tables 6-3 through 6-6, "Possible Failure Modes and Effects," on pp. 6-17 through 6-20.)
5. Identify possible leak paths of water into the connector assembly. (Figures 6-3 through 6-5 in section 6.1.3.2 show possible leak paths for two types of connector systems.)
6. Summarize qualitative results by determining critical paths or modes of system failure (that is, those combinations of component failures causing system failure) and the number or percentage of critical paths containing a particular component failure.

Table 6-2. Failure Modes

POSSIBLE FAILURE MODES	FAILURE CAUSE					
	INHERENT		INDUCED			
	Mfg/Design Deficiency	Material Deficiency	Instl/Assy Deficiency	Maintenance Deficiency	Excessive Operational Demands	Rough Handling
<u>Seals and Gaskets</u>						
1. Improper or poor bond of plug boot to plug shell	x		x	x		
2. Improper or poor bond of plug boot to cable	x		x			
3. Puncture leaks developing in plug boot due to voids	x	x	x	x		
4. Leakage due to corrosion damage to O-ring seat or groove	x	x	x	x		x
5. Improper O-ring groove design	x					
6. Water leakage into hull or receptacle due to loss or damage to receptacle-to-hull seals	x	x	x	x		x
7. Loss of receptacle-to-hull seal due to damaged O-ring seal surfaces and grooves			x	x		x
8. Degradation of physical properties of plug boot material due to seawater exposure	x	x				
9. Improper O-ring materials	x		x	x		
10. Loss of plug-to-receptacle seal due to contamination of O-ring sealing surfaces by foreign particles			x	x		
11. Plug-to-receptacle seal failure due to use of improperly sized O-rings	x		x			
12. Damaged plug shell gasket (seal; e.g., washer, O-ring)			x	x		x
13. Missing plug shell gasket			x	x		

Table 6-2, cont. Failure Modes

POSSIBLE FAILURE MODES	FAILURE CAUSE					
	INHERENT		INDUCED			
	Mfg/Design Deficiency	Material Deficiency	Instl/Assy Deficiency	Maintenance Deficiency	Excessive Operational Demands	Rough Handling
14. Improper gasket material	x	x	x	x		
15. Short circuit due to contamination of pin contact gasket	x		x	x		
16. Improperly bonded pin contact gasket	x					
17. Improper mating due to over-tolerance pin contact gasket thickness	x					
18. Damaged receptacle seal surfaces						x
19. Seal ring or washer fracture	x	x				
20. Material imperfections or impurities in plug boot	x		x			
21. Damage to plug thrust washer			x	x		
22. Missing receptacle-to-hull O-rings			x	x		
23. Damaged receptacle-to-hull O-rings			x	x		x
24. Seawater entry into hull interior due to improper seal of pin contacts to shell (following failure of plug-to-receptacle seals)	x		x	x		x
25. Seawater entry into junction box due to improper seal of pin contacts to web section (following failure of primary conductor seals)	x					
26. Seal failure of all molded rubber connectors following mating and unmating in arctic conditions	x	x	x	x		x
27. Voids in the mold boot of the connector	x	x				
28. Variation in durometer hardness and/or fit between molded rubber plug and receptacles resulting in seal failure		x				

Table 6-2, cont. Failure Modes

POSSIBLE FAILURE MODES	FAILURE CAUSE					
	INHERENT		INDUCED			
	Mfg/Design Deficiency	Material Deficiency	Instl/Assy Deficiency	Maintenance Deficiency	Excessive Operational Demands	Rough Handling
29. Inadequate bond between molded connector boot and connector shell	x	x				
30. Excessive molding flash in rubber connectors in the plug-to-receptacle seal areas	x		x	x		
31. Detachment of plug from receptacle due to explosion at plug-to-receptacle interface as a result of water entry past plug seal (short circuit fault current)	x		x	x		
32. Loss of electrical resistance of insulation due to hydrostatic pressure (pressure increases conductivity)	x	x				
<u>Receptacle or Plug</u>						
1. Coupling ring or receptacle threads improperly machined	x		x			x
2. Improperly located or sized plug shell key or receptacle shell keyway	x					
3. Corrosion of interface between plug shell and coupling ring or between coupling ring and receptacle shell	x	x		x		
4. Insulation breakdown due to moisture accumulation within receptacle	x	x	x	x		
5. Damaged or out-of-tolerance receptacle keyways	x		x	x		
6. Out-of-tolerance receptacle or plug shell dimensions	x					
7. Corrosion of hull or receptacle shell due to material incompatibility	x	x			x	
8. Corrosion due to material incompatibility of receptacle screws with hull	x					

Table 6-2, cont. Failure Modes

POSSIBLE FAILURE MODES	FAILURE CAUSE					
	INHERENT		INDUCED			
	Mfg/Design Deficiency	Material Deficiency	Instl/Assy Deficiency	Maintenance Deficiency	Excessive Operational Demands	Rough Handling
9. Corrosion due to material incompatibility of cover, receptacle, and junction box shell	x					
10. Corrosion due to material incompatibility of receptacle and hull	x					
11. Out-of-tolerance dimension on plug or receptacle shell and polarizing ring	x					
12. Lack of adequate plug-to-receptacle polarization in basic connector design	x					
13. Collapse of receptacle and connector shells due to hydrostatic pressure on web section	x	x			x	
14. Inadequate spacing between conductor terminations (movement during molding operation) in plug or receptacle that leads to electrical failure when cable seal is flexed or subjected to seawater pressure	x					
15. Out-of-specification plug or receptacle materials	x		x	x		
<u>Joint</u>						
1. Improper electrical or mechanical crimp joint	x		x	x		
2. Open circuit between socket contact and conductor						x
3. Insulation breakdown due to water or moisture entry into plug interior		x	x			x
4. Loosening of coupling ring due to shock or vibration	x		x		x	
5. Detachment of receptacle from hull due to impact forces on connector assembly	x				x	

Table 6-2, cont. Failure Modes

POSSIBLE FAILURE MODES	FAILURE CAUSE					
	INHERENT		INDUCED			
	Mfg/Design Deficiency	Material Deficiency	Instl/Assy Deficiency	Maintenance Deficiency	Excessive Operational Demands	Rough Handling
6. Damage of receptacle-to-hull fastening mechanism due to external shock or vibration	x	x	x	x		
7. Damaged cable jackets in the mold cable clamp area, especially in neoprene molded boots			x	x		x
8. Improper termination of braided shields resulting in braid ends piercing conductor insulation	x		x			
9. Cold soldered joints (conductor-to-socket connection)	x		x	x	x	
10. Plastic plug coupling ring failure due to impact forces	x			x		x
11. Failure of threads in plastic-bodied connectors	x			x	x	x
12. Improper termination of braided shields resulting in inadequate cable-to-connector tension strength	x	x	x			
<u>Insulators</u>						
1. Conductor insulation breakdown due to circuit overloading			x	x	x	
2. Insulation breakdown due to contamination (including foreign particles) of insulator materials	x		x	x		
3. Cracked or defective pin contact insulator	x	x	x	x	x	x
4. Socket contact not properly inserted in insulator			x	x		
5. Pin contact insulation breakdown due to contaminated material	x					

Table 6-2, cont. Failure Modes

POSSIBLE FAILURE MODES	FAILURE CAUSE					
	INHERENT		INDUCED			
	Mfg/Design Deficiency	Material Deficiency	Instl/Assy Deficiency	Maintenance Deficiency	Excessive Operational Demands	Rough Handling
6. Pin contact gasket insulation breakdown due to use of improper cleaning solvents			x	x		
7. Insulation breakdown due to contaminated pin contact face gasket	x		x	x		x
8. Withstanding voltage breakdown of pin contact insulation due to circuit overloading					x	
9. Insulation breakdown due to seawater pressure	x	x				
<u>Sockets</u>						
1. Open circuit due to damaged or missing socket contact spring	x	x	x	x		x
2. Socket contacts not located in proper center lines	x					x
3. Socket contacts not properly inserted in insulator	x		x	x		
4. Open circuit due to oversize socket contacts	x		x			
5. Open circuit due to contaminants in socket contact cavity			x			
6. Relaxation of the springs on the socket contacts	x	x				
<u>Pins</u>						
1. Open circuit due to undersize pin contacts			x			
2. Overloaded circuit leading to insulation breakdown of pin contact					x	

Table 6-2, cont. Failure Modes

POSSIBLE FAILURE MODES	FAILURE CAUSE					
	INHERENT		INDUCED			
	Mfg/Design Deficiency	Material Deficiency	Instl/Assy Deficiency	Maintenance Deficiency	Excessive Operational Demands	Rough Handling
3. Contaminated or corroded pin contact plating	x	x	x	x	x	
4. Bent or mislocated pin contacts preventing proper mating with plugs	x		x	x		x
<u>Conductors</u>						
1. Open circuit in conductors at socket contact interface due to fracture of nicked conductor strands			x			
2. Wearing through of the cable jacket due to improper support					x	
3. Conductor breakage due to axial tensile loads on the harness					x	x
4. Conductor breakage due to high impact loads on the cable or a sharp cable bend radius					x	x
5. Conductor kinking and breaking in the cable harness					x	x
<u>Potting</u>						
1. Insulation breakdown due to contaminated potting materials	x					
2. Potting material or pin contact insulation breakdown due to moisture accumulation	x		x	x		
3. Open circuit due to potting compound in socket contact	x		x	x		
<u>Interface</u>						
1. Loss of plug-to-receptacle seal due to foreign particles at interface			x	x		
2. Loss of boot-to-plug (also cable) seal due to contamination at the interface	x	x	x			

Table 6-3. Possible Failure Modes and Effects--Electrical Connector Plug

FUNCTION	ASSUMED TYPE OF FAILURE	POSSIBLE FAILURE CAUSE	EFFECT ON SYSTEM	BACKUP
Provide a rigid frame to withstand hydrostatic pressures and permit establishment of a watertight mating of external cable and connector plug	Warpage, fracture or collapse	Material imperfections or poor quality control	Loss of watertight envelope protection and eventual loss of electrical signal	None
	Moisture Seepage	Marred or scratched surface area that mates with receptacle O-ring	Electrolysis causes buildup of H ₂ and O ₂ gas pressure eventually blowing O-rings and loss of watertight envelop	None
Provide for positive mating of connector plug and receptacle	Loose or insufficient connection	Plug not completely inserted into receptacle	None - Proper tightening of coupling ring ensures depth of insertion	Coupling Ring
Provide proper alignment of sockets and pins during mating of plug and receptacle	Sockets do not mate properly with receptacle pins	Plug shell not properly aligned with the socket contact arrangement; alignment key out of position; receptacle shell not properly aligned with the pin contact.	Disruption of involved current flow	None
Provide primary pressureproof seal for plug and receptacle union (electronics housing)	Rupture or leakage	Material imperfections or fatigue; material surface interface marred or scratched; poor maintenance procedures.	None, redundant O-ring	Secondary O-ring
	Moisture seepage	Electrolysis action developing excessive gas pressures	Failure of both O-rings, loss of electrical signal	None
Isolate conductor from plug shell	Morrison seal or insulator breakdown and ultimate electrical short	Material impurities; material fatigue/age; fatigue induced by external cable vibration; moisture seepage/corrosion; resistance decreases as pressure increases.	Loss of watertight envelope and development of electrical short	None
Provide positive electrical path between external cable conductor and the receptacle contact pin	Open circuit	Defective alignment; rough handling; poor maintenance procedures; improper contact crimping; improper insertion of retainer ring	Ultimate loss of electrical signal	None
Provide a watertight envelope for interface of plug shell and external cabling conductors	Leakage or rupture	Material imperfection; improper/poor bonding; fatigue induced by external cable vibration; interface contamination; improper maintenance/handling; corrosion	Intermittent and/or disruption of current flow	None
Retain the mated connection of connector plug and receptacle	Wear, fracture, warpage or broken coupling ring lip	Material imperfections or poor quality control; fatigue induced by external cable vibration and improper tightening	Loss of watertight envelope and development of electrical shorts	None
			Loss of connection resulting in development of an electrical short.	None

Table 6-4. Possible Failure Modes and Effects--Electrical Connector Receptacle

FUNCTION	ASSUMED TYPE OF FAILURE	POSSIBLE FAILURE CAUSE	EFFECT ON SYSTEM	BACKUP
Provide a rigid frame to withstand hydrostatic pressures and permit establishment of watertight mating	Warpage, fracture or collapse	Material imperfections or poor quality control	Loss of watertight envelope protection and eventual loss of electrical signal	None
Provide for positive mating of connector receptacle and plug	Loose or insufficient connection	Plug not completely inserted into receptacle; worn or stripped threads for coupling ring union	None--Proper tightening of coupling-ring ensures length of engagement	Coupling Ring
Provide a proper alignment of pins and sockets during mating of receptacle and plug.	Pin contacts do not mate properly with receptacle pins	Receptacle shell not properly aligned with pin contact arrangement; alignment key out of position; plug shell not properly aligned with the socket contact arrangement.	Disruption of involved current flow	None
Backup watertight seal for plug-to-receptacle union	Moisture or water seepage, leakage/rupture	Material imperfections or fatigue; O-ring surface marred or scratched; maintenance-induced failure; excessive buildup of H ₂ and O ₂ gases caused by electrolysis action; foreign materials	Increasing current loss; eventual loss of involved signals	None
Insulate pin contacts from receptacle shell	Electrical short	Insulation breakdown due to impurities within the insulator; material fatigue/age.	Increasing loss of transmitted signals	None
Provide support and insulation of pin contacts	Electrical short	Improper installation; material fatigue/age; deficient maintenance procedures; resistance decreases as pressure increases (material deficiency)	Eventual loss of involved electrical signals	None
Provide positive electrical connection between conductor and the socket contact	Open electrical circuit	Improper or cold solder connection; defective alignment key; use of excessive force for inserting plug into receptacle; deficient maintenance procedures	Intermittent or complete loss of involved electrical signal	None
Provide a watertight seal for receptacle to component at interface	Moisture or water seepage; leakage or rupture	Material imperfection or fatigue; interface surfaces marred or scratched; poor maintenance procedures; improper torquing of coupling ring; foreign materials	None, redundant O-ring	Secondary O-ring

Table 6-5. Possible Failure Modes and Effects--Receptacle in Hull

FUNCTION	ASSUMED TYPE OF FAILURE	POSSIBLE FAILURE CAUSE	EFFECT ON SYSTEM	BACKUP
Provide pressureproof penetration of hull	Water leakage past primary seal	Seal surfaces damaged; faulty seal; foreign materials in interface	None	Secondary O-ring
	Water leakage past secondary seal	(same as above)	Water leakage into pressure hull	None
Provide pressureproof seal for plug or junction box	Water leakage past primary seal	(same as above)	None	Secondary O-ring
	Water leakage past secondary seal	(same as above)	Water contamination of enclosed contacts: short circuiting	Primary O-ring on outboard header
Provide positive mating and support for outboard component	Loose or insufficient retention	Improper torquing of coupling ring	None	Secondary O-ring
Provide proper alignment of contacts with mating component	Contacts do not mate properly due to damage	Defective key and/or keyways in components	Loss of damaged circuits	Double keys intended to prevent "scoop-type" contact damage
Provide a pressureproof envelope for enclosed electrical wiring	Fracture or cracking	Defective material or damaged material	Loss of all components serviced by connector due to flooding	Inboard hull waterdam

Table 6-6. Possible Failure Modes and Effects--Junction Box Hull

FUNCTION	ASSUMED TYPE OF FAILURE	POSSIBLE FAILURE CAUSE	EFFECT ON SYSTEM	BACKUP
Provide rigid, pressure-proof foundation for electrical connectors	Water leakage past receptacle/ junction box primary seal	Seal surfaces damaged; faulty seal; improper tightening of receptacle mounting screws	None	Receptacle junction box secondary seal
	Water leakage past receptacle/ junction box secondary seal	(same as above)	Flooding of internal wiring	None
	Water leakage past contact insulator seal	Faulty glass	Degraded and possible loss of receptacle circuit	None
Provide a pressureproof envelope for enclosed electrical wiring	Cracking or collapse	Defective material	Flooding of internal wiring	None
Provide access to internal wiring of junction box (pressure-proof cover)	Water leakage past cover/ junction box primary seal	Seals or seal surfaces damaged	None	Secondary seal
	Water leakage past cover/ junction box secondary seal	(same as above) plus improper fitting of cover	Flooding of internal wiring	None
	Distortion or collapse of cover	Defective material; collision	Flooding of internal wiring	None

7. Implement results; i.e., recommend to design engineers redesigning options that will rectify the possible failure modes.

As quantitative data on failures and their causes become available, the FMA can be made increasingly quantitative. The procedure for a quantitative method is outlined below.

Quantitative FMA Procedure Outline

1. Determine Component Characteristics

- a. Basic data:

failure rate, λ , and repair time, τ , if applicable

- b. Basic component probabilities:

p = probability of failure

$p = \lambda t$, where t = operating time

q = probability of being inoperable due to repairable failure

$q = \lambda \tau$

2. Determine Critical Path and System Characteristics

- a. All components, nonrepairable:

P_i = probability of system failing by a particular critical path (critical path probability)

$P_i = p_1 p_2 \dots p_m$ (product of component probabilities)

P_s = probability of system failure (system probability)

$P_s = \sum_{i=1}^N Q_i$ (sum of critical path probabilities)

- c. Mixture of repairable and nonrepairable component failures:

Apply the general rule, i.e., multiply appropriate component probabilities to obtain critical path probability; sum critical path probabilities to obtain system probability.

3. Determine Quantitative Importance

- a. Critical path importance

I_i = fraction of time system failure caused by a particular critical path

$$I_i = \frac{\text{critical path probability}}{\text{system probability}}$$

b. Component importance

i_k = fraction of time a particular component failure
is one of the causes of system failure

$$i_k = \frac{\text{sum of critical path probabilities containing component}}{\text{system probability}}$$

4. Evaluate Sensitivity

Perform a sequence of calculations in which different values are used for λ and/or τ to determine the effect of changes in system characteristics. Changes can also be made in the fault tree to determine the impact of design modifications.

5. Perform Error Analyses

A statistical analysis to determine the possible error in any final result due to possible errors in the data used. One applicable technique is Monte Carlo simulation.

6. Implement the Results

Communicate the results to engineering for incorporation in design reviews, redesign, quality control and procedures, and performance/failure analyses.

6.1.3.2 Possible Leak Paths. This section presents illustrations of possible leak paths of water into two models of underwater connectors. The first illustration, Figure 6-3, shows seven leak paths into a Morrison-type sealed connector. Numbered components of the Morrison seal may be identified by referring to the table on pp. 3-12 and 3-13. Leak path 1 produces a short between the center conductor and the ground shield, and shorts in electronic packages. Leak paths 2 and 3 proceed past the nut and follow cable jackets on the inside of the Morrison seals to produce shorts at the points indicated. Leak path 4 proceeds past the nut and follows the housing wall on the outside of the Morrison seals to produce shorts at the points indicated. Leak paths 5 and 6 are examples of seawater hosing into the connector from a leak in the cable. Leak path 1 is the most likely to occur.

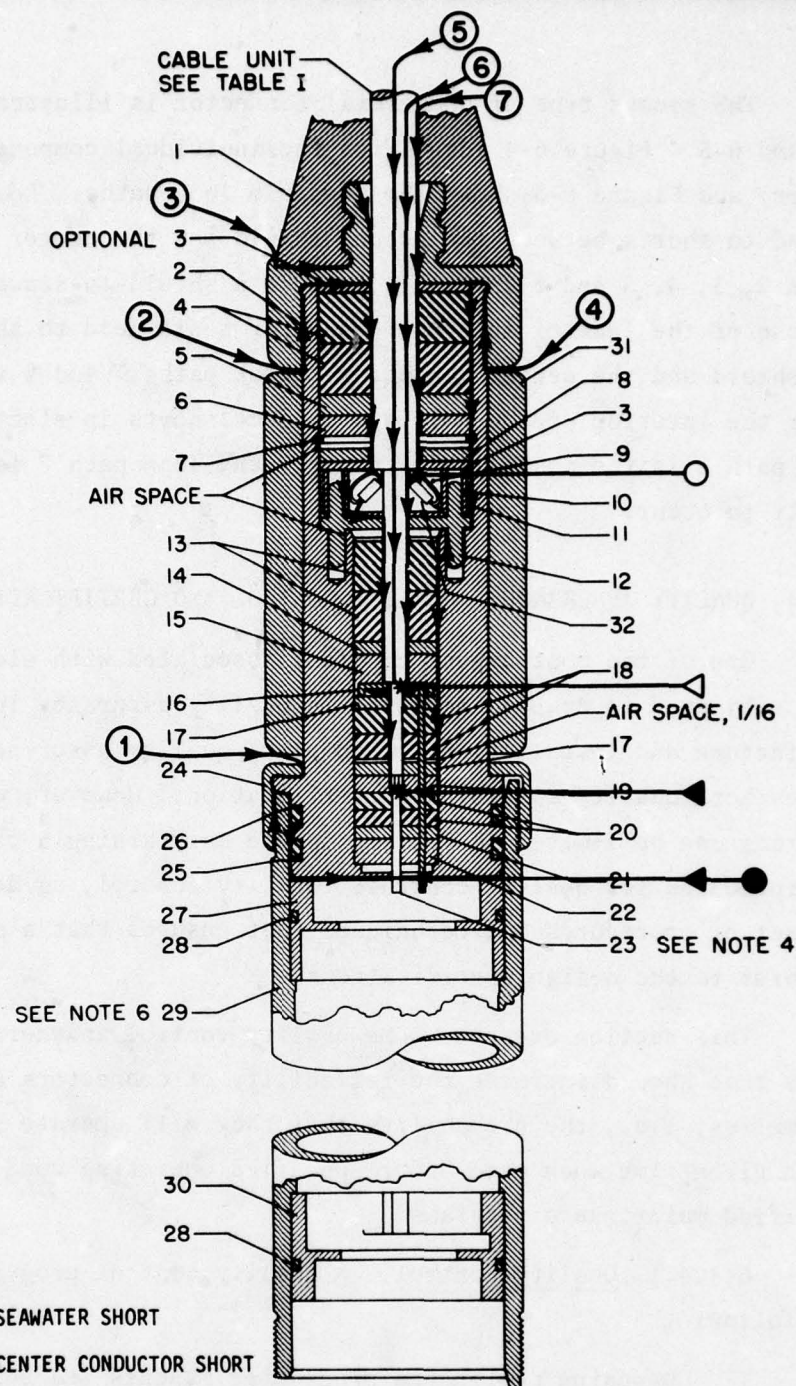


Figure 6-3. Possible Leak Paths into a Morrison-Type Sealed Connector

The second type of commercial connector is illustrated in Figures 6-4 and 6-5. Figure 6-4 identifies the individual components of the connector, and Figure 6-5 shows the possible leak paths. Leak paths 1 through 6 lead to shorts between the ground shield and the center conductor. Leak paths 2, 3, 4, 5 and 6 initially produce a shield-to-seawater short but because of the lack of internal connector seals lead to shorts between the shield and the center conductor. Leak paths 7 and 8 allow seawater to enter the interior of the hull and produce shorts in electronic packages. Leak path 2 is the most likely to occur and leak path 7 is the next most likely to occur.

6.1.4 QUALITY ASSURANCE: QUALITY CONTROL AND CERTIFICATION GUIDELINES

One of the most urgent problems associated with electrical components subjected to deep submergence is quality assurance in their design, manufacture and installation. A complete quality assurance program includes both quality control and certification. However, quality assurance programs can be limited to setting up and maintaining a comprehensive set of procedures for quality control. Quality control, as defined here, is the set of procedures and techniques that ensures that a manufactured item conforms to the design specifications.

This section presents some quality control and certification procedures that should increase the reliability of connectors and connector assemblies; i.e., the probability that they will operate satisfactorily for a given time when used under specified operating conditions and with specified maintenance programs.

6.1.4.1 Quality Control. A quality control program would include the following:

1. Composing design and procedures manuals and ensuring that the manuals are available to the proper people for reference.
2. Labeling all procured materials, verifying their suitability and controlling all materials issued for production.

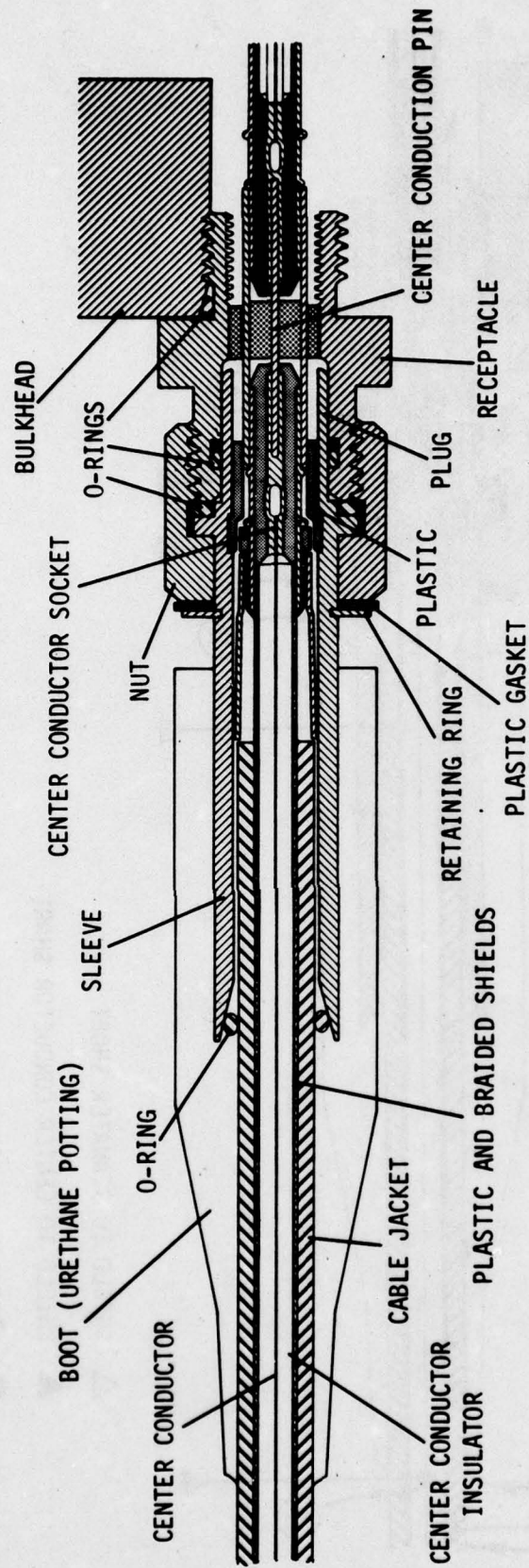
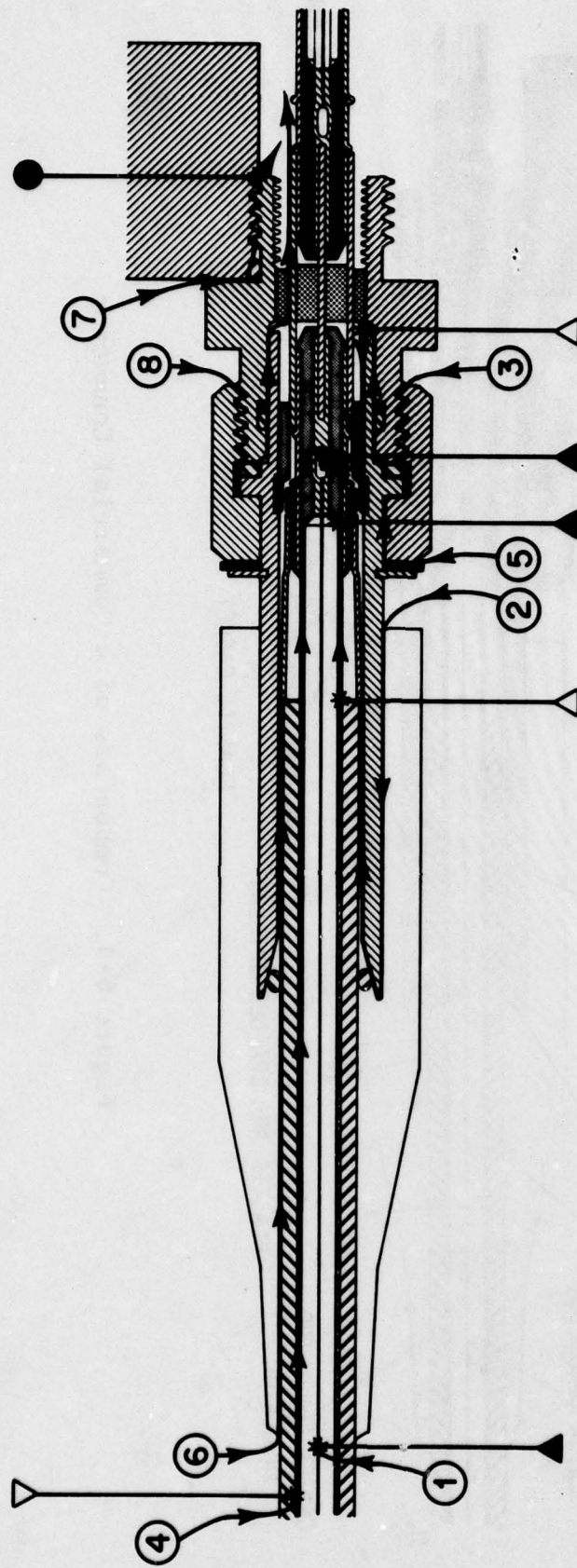


Figure 6-4. Components of a Commercial Connector



- △ SHIELD TO SEAWATER SHORT
- ▲ SHIELD TO CENTER CONDUCTOR SHORT
- ELECTRONICS PACKAGE TO SEAWATER SHORT

Figure 6-5. Possible Leak Paths of a Commercial Connector

3. Maintaining inspections during the manufacturing process.
4. Maintaining a system for identifying, serializing and certifying completed components.
5. Inspecting, testing and certifying completed components.
6. Assuring that the latest applicable drawings and information are available at the time of inspection.
7. Maintaining a performance/failure analysis feedback program.
8. Establishing procedures for installation and maintenance of components.
9. Maintaining records of all quality control inspections and tests.
10. Maintaining gauges and testing devices necessary to ensure that components conform to specifications.
11. Providing procedures and instructions for control of stored supplies and finished components.
12. Utilizing packaging devices to protect components during handling.

In the case of deep submergence connectors and connector assemblies, the above quality control requirements should be written into or referenced in the following documents:

1. The cable specifications
2. The plug specifications
3. The receptacle specifications
4. The hull specifications
5. The harness specifications
6. The connector assembly, installation and maintenance manuals.

6.1.4.2 Certification. While a quality assurance program may be limited to quality control, a complete program also includes certification. Certification of electrical connectors requires that all operations be conducted in accordance with an established set of standards. These standards normally cover the following items:

1. Design requirements and guidelines
2. Design calculations
3. Design verification
4. Material selection evaluation
5. Material verification
6. Seal material verification
7. Assembly and detail drawings
8. Failure mode analyses
9. Preproduction qualification test procedures
10. Production quality conformance procedures
11. Handling procedures
12. Installation procedures
13. Maintenance procedures
14. Periodic performance/failure analyses

The following sections discuss these certification areas in more detail.

6.1.4.1.1 *Design requirements and guidelines.* Design certification requirements for submerged electrical connectors include:

1. Operating depth
2. Test pressure
3. Vibration
4. Physical shock
5. Amperage
6. Voltage
7. Frequency
8. Temperature
9. Hull and structural support materials

The following are suggested design certification guidelines:

1. Through-the-hull receptacles should have primary and secondary seals.
2. Connectors must be fabricated from acceptable corrosion-resistant materials that are galvanically compatible with

the hull. All galvanically incompatible materials must be electrically isolated by a resistance of at least 100,000 ohms.

3. Materials and processes for preventing corrosion of connectors and seals, such as paints and sealants and their application, must be specified.
4. All connectors must be capable of withstanding all potential hydrostatic pressures.

6.1.4.1.2 *Design calculations.* The design calculations should ensure that the connector components are properly sized to prevent collapse or fracture due to the operating environment, and that all seals are properly sized.

6.1.4.1.3 *Design verification.* Design verification consists of tests to prove that the design is adequate to meet the physical and mechanical requirements imposed by the expected service conditions. Design verification testing of the connector components should follow the basic test sequence outlined in Table 6-7. Some of these tests will be repeated in the preproduction qualification test sequence and in the production quality conformance test sequence. The following performance requirements apply to all three test sequences:

Table 6-7. Design Verification Test Sequence for Connectors

TEST NO.	DESCRIPTION	PLUG	RECEPTACLE	MATED WIRED CONNECTORS
1	Examination of Product	x	x	x
2	Insulation Resistance Test	x	x	x
3	Continuity Test	--	--	x
4	Contact Resistance Test	x	x	--
5	Withstanding Voltage Test	x	x	x
6	Durability Test	--	--	x
7	Hydrostatic Pressure Test	x	x	x
8	Thermal Shock Test	x	x	x
9	Vibration Test	--	--	x
10	Shock Test	--	--	x
11	Withstanding Voltage Test	--	--	x
12	Insulation Resistance Test	x	x	x
13	Examination of Product	x	x	x

Insulation Resistance: Connectors should be insulation-resistance tested in accordance with Method 3003 of MIL-STD-1344. The resistance should be measured between all adjacent pairs of contacts and between the metal shell and each contact. The test voltage must not exceed the rated voltage of the test connector or connector system. The insulation resistance should be greater than 5000 megohms.

Continuity: All mated connectors and wired contacts should be checked for continuity with a standard circuit tester. There should be no evidence of open circuits.

Contact Resistance: The contact resistance should be measured in accordance with the contact resistance test of MIL-STD-1344. The potential drop should not be greater than that determined during the design program.

Dielectric Withstanding Voltage: Mated and unmated connectors should be tested in accordance with Method 3001 of MIL-STD-1344. The applicable test voltage (1000 volts for size 20 and 16 contacts, and 1900 volts for size 12, 8, 4, 0 and 0000 contacts) should be applied between all adjacent contacts and between all contacts and the metal shell.

Durability: Sample connectors should be mated and unmated 150 times at a rate of 50 ± 25 cycles per hour; the plug coupling rings should be operated in a manner to simulate actual service. One third of the unmatings should be performed by pulling on the plug and the receptacle. One third of the unmatings should be performed by pulling on the cables. The pull should be twice that required for normal unmating. The force can be controlled by attaching the plug and receptacle to a dash pot system. One-third of the unmatings should be performed by jerking the cables. The jerk may be accomplished by producing within a few milliseconds a cable velocity of $10 \text{ ft/sec} \pm 5 \text{ ft/sec}$ in the cable no more than 2 feet from the connector. This can be accomplished by using a rotating arm that contacts a catch attached to the cable. Sample connectors should show no damage detrimental to the operation of the connector as a result of the test.

Continuity should be continuously monitored during the test. There should be no interruption of electrical continuity longer than 10 msec in the mated condition. During mating and unmating the continuity of all conductors should change simultaneously. No conductor should change continuity more than 10 msec before any other conductor.

Hydrostatic Pressure: The unmated plugs and receptacles and the mated connector assemblies should be subjected to a hydrostatic pressure test. The connector assemblies should be mounted on the internal side of a pressure vessel cover using the mounting method to be used in the field. All standard precautions must be complied with. For the unmated connector tests, the face of the web section should be exposed to a test pressure equivalent to 1-1/2 times the connector operating pressure. The connectors may be tested in clean tap water. For the mated connector and pressure-proof cover tests, the connectors should be mated with the tools that will be used in the actual installation and held with the normal locking device. The connector should be wired as it will be in service. See Figure 6-6 for an example of a mated connector test circuit. The cable should be end-sealed using the same techniques used to mold the cable to the plug.

The assembly should be tested at 1-1/2 times the operating pressure of the connector on a test schedule similar to that shown in Table 6-8 except that the depth classification should be 1-1/2 times the connector operating pressure. The connectors should be subjected to 10 cycles of the hydrostatic pressure test sequence. Insulation resistance readings should be measured before, during and following every pressure cycle. There should be no evidence of mechanical damage, water leakage or impaired electrical properties in the plugs, receptacles or mated connectors as a result of these tests.

Vibration: Mated connectors and mated pressureproof covers should be vibrated in accordance with Method 2005 of MIL-STD-1344. Mated

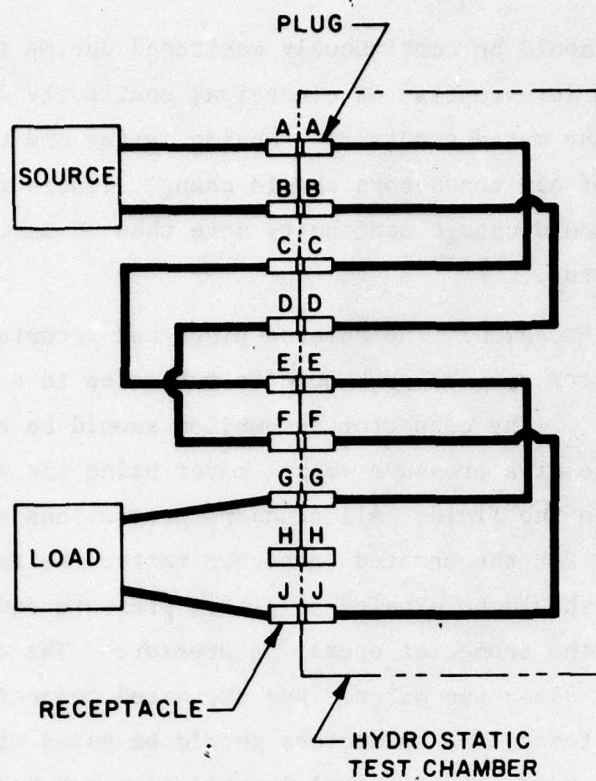


Figure 6-6. Mated Connector Test Circuit

Table 6-8. Hydrostatic Pressure Test Schedule

STEP	PRESSURE (psig)		HOLD TIME (Min)	DEPTH CLASSIFICATION (ft)
	Low	High		
1	0	20	5	
2	0	20	5	
3	0	20	5	
4	0	150	5	
5	0	1,000	5	
6	0	2,000	5	
7	2,000	3,000	5	
8	3,000	5,000	5	
9	5,000	6,000	5	
10	5,000	8,000	5	
11	8,000	10,000	5	
12	10,000	12,000	5	
13	12,000	13,600	24 hours	20,000

AD-A036 841

WASHINGTON UNIV SEATTLE APPLIED PHYSICS LAB
INTERFERENCE SEALS AND CONNECTORS FOR UNDERSEA
JUL 76 J PARADIS

F/6 13/10
ELECTRICAL APPLI--ETC(U)
N00017-74-C-1208

UNCLASSIFIED

4 OF 4

AD
A036 841



NL

END

DATE
FILMED
4-77

contacts should be wired in series as noted in Figure 6-6, and be connected with a suitable testing circuit. Any voltage or current within the connector rating should be applied throughout the vibration test. The mated connector or mated pressureproof cover should be held together by the normal locking device. Cables should be supported on a stationary frame not closer than 8 inches from the connector. Mated connectors should not be damaged as a result of this test, and there should be no loosening of parts. Sample connectors should remain in full engagement, and there should be no interruption of electrical continuity longer than 10 msec.

Shock: Mated connectors and mated pressureproof covers should be tested in accordance with Method 2004 of MIL-STD-1344. Three blows should be applied in each direction of the three major axes of the connectors. Receptacles should be mounted on the device or carriage. For the mated connector tests, molded plugs should be engaged to the receptacles and held only by normal locking means. All contacts should be wired in series as shown in Figure 6-6, and the cables or wire bundles should be clamped to the structures that move with the connectors. A minimum of 8 inches of cable should be unsupported behind the rear of each connector. For the mated pressureproof cover tests, the covers should be mated to their respective plugs or receptacles and mounted to the shock device or carriage. The covers should be held by the normal locking device. Mated connectors should not be damaged as a result of these tests, and there should be no loosening of parts. Sample connectors should be retained in full engagement and there should be no interruption of electrical continuity longer than 10 msec.

6.1.4.1.4 *Material selection evaluation.* Selection criteria and test procedures to determine the suitability of the selected materials should be part of a design certification package. Standard material specifications such as military specifications or ASTM, NAS, AISI or SAE standards should be used whenever possible. Design criteria for material selection should preclude the use of noncorrosion-resistant materials. (For seawater applications, a corrosion rate of 5 mils per year is usually

considered the dividing line between corrosion-resistant and noncorrosion-resistant materials.) All electrically connected metals should be galvanically compatible (i.e., close on the galvanic series). Corrosion prevention begins with proper material selection and by specifying procedures such as painting, sealing and a cathodic protection system to reduce corrosion. The MIL-STD-202 test method is applicable, but it is strictly a comparative test of materials and coatings. The initial design decisions on materials and processes should be verified by laboratory and field tests. The effectiveness of the material selection process will, of course, ultimately be determined by the results of the performance/failure analyses on hardware recovered from field service.

6.1.4.1.5 *Material verification.* Acceptance/rejection criteria for material verification should be presented so that materials can be accepted or rejected on the basis of the results from standard or specified laboratory or field tests. All such test results should be kept available for the life of the product. Depending on the procurement specifications, the tests may be conducted by the supplier, the receiver or both.

6.1.4.1.6 *Seal material verification.* Seal material verification, especially for Morrison seals, requires checking for durometer hardness and bulk resistivity. The bulk resistivity should be measured at pressures greater than the expected service pressure, and the measurements should be repeated after the pressure has been maintained for at least 24 hours. The resistivity should not decrease with increased pressure below the design value. The results of these tests should be saved for comparison with the results of performance/failure analyses conducted at a later date.

6.1.4.1.7 *Assembly and detail drawings.* The assembly and detail drawings should be sufficiently complete to allow the manufacturer to fabricate a complete connector or connector assembly.

6.1.4.1.8 *Failure mode analyses.* For a complete description of Failure Mode Analysis, refer to Section 6.1.2.

6.1.4.1.9 *Preproduction qualification tests.* Once a connector design is verified, the user must ascertain whether the fabricator can produce a satisfactory product using the specified material. The preproduction qualification tests verify the manufacturer's ability to fabricate the connector components. Passing these tests allows the manufacturer's products to be placed on the Qualified Products List (QPL) of the applicable connector specification. The preproduction qualification tests should follow the basic test program outlined in Table 6-9. For a more detailed explanation of what the tests entail, see the discussion on the design verification tests in section 6.1.4.1.3.

Table 6-9. Preproduction Qualification Test Sequence for Connectors

TEST NO.	DESCRIPTION	PLUG	RECEPTACLE	MATED WIRED CONNECTORS
1	Examination of Product	x	x	x
2	Insulation Resistance Test	x	x	x
3	Continuity Test	--	--	x
4	Contact Resistance Test	x	x	--
5	Withstanding Voltage Test	x	x	x
6	Hydrostatic Pressure Test	x	x	x
7	Thermal Shock Test	x	x	x
8	Withstanding Voltage Test	--	--	x
9	Insulation Resistance Test	x	x	x
10	Examination of Product	x	x	x

6.1.4.1.10 *Production quality conformance tests.* The production quality conformance tests should be conducted as outlined in Table 6-10. (Again, refer to the explanation given for the design verification tests.) These tests should be run on each completed connector assembly prior to shipment to the customer. All test data should be recorded and preserved.

Table 6-10. Quality Conformance Test Sequence for Connectors and Accessories

TEST NO.	DESCRIPTION	PLUG	RECEPTACLE	PRESSURE- PROOF COVERS
1	Examination of Product	x	x	x
2	Insulation Resistance Test	x	x	--
3	Withstanding Voltage Test	x	x	--
4	Hydrostatic Pressure Test	x	x	x
5	Insulation Resistance Test	x	x	--
6	Examination of Product	x	x	x

6.1.4.1.11 *Handling*. Handling procedures should specify that electrical connectors and accessories should be protected with end caps and sleeves at all times when they are not being inspected, tested or otherwise used from the time of manufacture to installation. The caps are to protect the contacts, pins, threads and conductors from mechanical and corrosion damage and contamination; the sleeves are to protect the housings, rings and coatings from mechanical damage. It should also be specified that the relative humidity in storage areas should not exceed 65%.

Some special precautions that should be specified when examining connectors include the following:

1. Capping plugs and Receptacles. Whenever a cable harness is disconnected, metal caps should immediately be placed on the plug and receptacle to prevent the entry of foreign material or possible damage.
2. Testing precautions. Before measuring current leaks in connected cable harnesses with a megger (megaohm meter), be sure that the connectors and connected equipment can withstand the applied voltage.
3. Cleaning contaminated plugs and receptacles. In the event that the receptacle or plug faces become contaminated by salt

water or other foreign material, the receptacle or plug should be swabbed out with distilled water and dried with dry nitrogen. The operation should be repeated as necessary until adequate insulation resistance values are obtained.

4. Connector remating precautions. Caution should be specified when mating plug-to-receptacle connectors to ensure that the proper plug is mated to the proper receptacle. If they are physically matched, but are electrically mismatched, damage to the equipment can result. If attempts are made to mate the plugs to receptacles with mismatching key orientations, physical damage to the plug or receptacle can result. These keyway deviations may not be readily discernible to the eye.

6.1.4.1.12 *Connector system installation guidelines.* The connector systems must be installed according to strict quality control requirements even though the installation may be performed on board a ship at sea. Proper quality control can be achieved by observing the following rules:

1. The work must be accomplished according to specific procedures.
2. The personnel installing the connectors must be familiar with the procedures and have the manuals available.

The procedures should specify the inspections and checks that are to be conducted in the shop and at the installation site. Some of these checks include the following:

1. Check the harness assembly in the shop to determine if the connectors and assembly have passed the electrical and mechanical tests prescribed.
2. Remove the protective caps from the plugs (or receptacle) on each end of the cable and check the O-rings and O-ring seal surfaces for dirt, nicks and scratches. All O-rings should be coated with a thick film of lubricant. The O-ring

groove and all clearance volumes on the water side of the O-rings should be completely filled with O-ring lubricant or grease.

Special precautions should be specified when installing O-rings. O-rings should be packaged until ready for assembly and handled with care to prevent damage. They should be installed or removed with an O-ring tool made from semirigid plastic; knives, picks and other sharp objects should not be used as they may damage the O-ring or groove surfaces. The connector O-rings should not be installed until the connector is to be put into service. The O-rings should be lubricated with a thick film of MIL-L-4343 lubricant prior to installation. To obtain the desired seal, the ring grooves must be free of dirt and other foreign particles, and the O-ring must be free of nicks, dents or flats. MIL-STD-413, "Visual Inspection Guide for Rubber O-rings," should be followed to determine the adequacy of the O-rings for installation.

Barring damage, the O-rings should last at least 5 years. After that time, they should be replaced because the O-ring material may take on a permanent set and flatten out in the seal area.

If an O-ring is to be replaced, the replacement O-ring drawn from stock should be carefully handled and visually inspected for defects. MIL-STD-413 aptly shows the major defects that can occur during O-ring manufacture. The procedure should specify that MIL-STD-413 should be referred to when inspecting O-rings. A helpful reference when reporting defects is MIL-STD-177, "Terms for Visible Defects of Rubber Products." Basically, the O-ring should be sized in accordance with the specifications, and excessive flash, back rind, dents, depressions, flow lines, bad fillings that cause dents and depressions, foreign materials and splits. The O-ring thickness can be checked with a micrometer.

O-rings are packaged in dated containers. O-rings with a cure date older than 24 months should not be used.

The identification on the O-ring package should include the dimensions and material. Size is usually designated by referencing the ARMY-NAVY (AN) standard or Military Standard (MS) drawing number that shows

the dimensions to which the O-ring must conform. A commonly used O-ring material for salt water applications is a BUNA-N compound that conforms to MIL-P-5516, Class B, and MIL-P-25732.

6.1.4.1.13 *Maintenance*. The maintenance procedures will vary according to the application and will not be discussed here.

6.1.4.1.14 *Performance/failure analyses*. For a complete description of Performance/Failure Analysis, refer to Section 6.1.5.

6.1.5 PERFORMANCE/FAILURE ANALYSIS PLAN

6.1.5.1 Introduction. Underwater connector systems are normally recovered and replaced after several years of service, either because of component failure or because of probable impending failure. Regardless of the reason for retrieving the system, it is advisable that a performance/failure analysis be made to identify which components have failed (if any), determine the cause(s) of failure, and document the performance of the connector system and its parts. In the short term, the results of performance/failure analyses help improve the soundness of connectors and connector assembly designs, material selections, and processing. In the long term, such information helps quantify the reliability of both inhouse components and individual parts purchased from different manufacturers. The following section presents a plan for a performance/failure analysis of an underwater electrical connector system (acoustic array).

6.1.5.2 Preparation. The first step is to obtain background information on the underwater connector arrays to be recovered. Pertinent information includes the array number, type of array, date planted, operating depth, corrosion protection system (description of paint system and cathodic protection systems), array performance, individual connector performance characteristics, reason for array recovery, and suspected component failures.

6.1.5.3 Recovery Procedure. The next step is to inspect the array and harness at the time of recovery and dismantling and record all observations of connector system condition.

1. Preparation data should be confirmed as possible by inspecting the array. Anode size, location and percent weight change should be recorded. The type of paint system and its condition should be noted. The array structural materials should be determined as possible by inspection.
2. Color slides or photographs will be taken to show the condition (degree of corrosion, extent of fouling and mechanical damage) of the array at the time of recovery. The photographs should include closeups (from 1 to 2 ft, with a 55-mm macro-lens or equivalent) of fasteners, connectors, anodes, representative painted surface areas and the corroded areas with the worst damage. In addition, overall photographs of the array will be taken. High-quality photographic equipment and professional techniques will be used to assure the quality of the photographic information. All photographs will be identified with the array number and the specific location of the part depicted.
3. The complete connector assembly (or harness), including the junction box, plus 3 ft of shoreside cable will be carefully dismantled intact. The intact harness will then be gently washed down with fresh water. Protective caps (aluminum) will be attached over acoustic hydrophones. The electrical cable will be cut about 3 ft to the shore side of the junction box. To ensure that no water enters the open cable end, a hose clamp will be clamped around the cable 2 to 3 in. toward the junction box from the cut location before the cut is made. Immediately after parting the cable, a heavy duty (10-mil thick) plastic bag will be fixed over the salvaged end with a second hose clamp.
4. The harness will be identified with the array number and the position of each hydrophone on the array will be indicated.
5. The complete harness will be placed on a wooden board or pallet, and the junction box bolted to the board. This

assembly will be set in a heavy duty plastic bag inside a wooden box or other sturdy container. The entire harness shall remain on top of the board and no part shall be allowed to sit in water in the bottom of the bag. Approximately five pounds of desiccant (silica gel) will be placed in the bag. A vacuum will be pulled on the bag to pull it tightly around the assembly and extract as much air as possible. The bag will be back-purged with nitrogen or argon, and then sealed under vacuum. The box will be covered and kept out of the sun (preferably in cold storage, but above freezing). water-displacing compounds and solutions must not be used because their effect on leak sites and corrosion damage is not well known.

6. Shipment to an examination site will be made as soon as possible by air freight or rapid surface transport. The top of the box will be plainly marked "THIS SIDE UP."

6.1.5.4 Examination, Test and Analysis. Visual inspection will be made of all connector assemblies for evidence of damage during shipment. Observations will be recorded.

1. Before disconnecting the connectors, a complete acoustic/electronic test will be performed on each harness (connector/hydrophone assembly). The continuity of all input and output circuits will be checked for open circuits. The sensitivity and beam pattern of each hydrophone will be recorded individually and compared with preservice test records. These comparisons will be analyzed to evaluate the deterioration of each connector/hydrophone assembly. It shall be kept in mind that the primary objective of this analysis is to identify any parts (connectors, seals, cables, housings or electronics) that have been damaged by corrosion, leaks, dampness, deformation, fault currents or shorts.
2. All mated connectors and wired contacts will be checked for continuity with a standard circuit tester. The electrical

resistance across all connector pins and between pins and housings will be measured in accordance with Method 3033 of Mil-Std 1344. The objective of these measurements is to detect low-resistance paths in the connectors or harness due to seal material breakdown, leaked water or corrosion products.

3. Mated and unmated connectors should be tested in accordance with Method 3001 of Mil-Std 1344 to determine connector and connector system dielectric withstanding voltage.
4. The contact resistance will be measured in accordance with the contact resistance test of Mil-Std 1344 and recorded.
5. A failure analysis will be performed on all connectors, junction boxes, spheres and cables that show evidence of failure (low resistance, low sensitivity, leakage or corrosion damage), with the objective of identifying the failure mode and the cause of failure. Disassemble connectors carefully to preserve all parts (seals, O-rings, O-ring surfaces, grooves, keys, spacers, pins, retainers, housing, etc.). Visually examine parts for damage (corrosion and handling). Note the condition of surfaces, grooves, sealants and coatings (lubricants, paints and anodizing). Identify leak paths and probable weakest link in connector. Corrosion damage and corrosion products often indicate the leak path. Select parts and areas for examination with an optical microscope and/or scanning electron microscope (SEM) as necessary. Examination with a SEM can verify material quality, identify corrosion products, quantify corrosion damage and indicate crack nucleation sites; i.e., provide substantial information on the cause of failure. Verify that all connector materials are the same as those specified by design. Wet chemistry and dry chemistry (spectrographic or X-ray) methods will be used as necessary. Section and mount specimens for metallographic examination as necessary to evaluate corrosion damage or inherent defects. Record and summarize observations. Connectors that do not exhibit evidence of failure will be examined to a lesser degree using

the same technique. Evidence of no failure as well as of failure will be recorded.

6. The service performance of the selected connector seal materials will be evaluated by determining hardness, dimensional changes (creep), and changes in bulk resistivities at various pressures. Present hardness, dimensions and bulk resistivities will be measured and compared with preservice dimensions and resistivities.

6.1.5.5 Report. Observations, test results, analysis results and conclusions will be documented. Conclusions will emphasize evidence of successful operation as well as probable failure modes and cause(s) of failure(s). Recommendations to prevent the failures and comments on the apparent best design(s) (geometry, materials and assembly procedures) will be included in the report.

6.1.5.6 Application of Results. The results and conclusions of performance/failure analyses should be communicated to design and quality control engineers for use in design, design reviews and redesign.

6.1.6 DIRECTIONS FOR FUTURE RESEARCH

In the process of writing the manual, it became evident that specific research and development programs on submerged connectors are needed. Among these programs are the following:

1. Tests should be performed to determine the pressure limits on connectors with Morrison seals over a reasonable range of design parameters such as cable crush strength, washer stiffness, housing-to-washer clearance, and seal material creep strength.
2. A Morrison seal material study should be conducted to evaluate material properties and behavior, and to develop material specifications and tests for candidate seal materials.

3. A study of boot potting compounds should be performed to evaluate adhesion properties and behavior, and to determine mixing, storing, preparation, and application procedures for candidate potting compounds.
4. Corrosion research should be undertaken to provide engineering background for the understanding and prevention of several different corrosion mechanisms:
(1) corrosion mechanism under O-rings, (2) corrosion mechanism under Morrison seals, (3) effects of cathodic protection on seal corrosion, and (4) effects of greases and paint systems on seal corrosion, to name a few.
5. A compact connector tester with the facilities to perform all or most of the design verification tests (refer to Section 6.1.4) should be developed.
6. A procedure for performing a performance/failure analysis on all recovered submerged connector systems should be written and adopted; the results should be periodically incorporated into the reference manual.
7. A Failure Mode Analysis or Fault Tree Analysis should be performed on selected connectors and connector assemblies that are presently in service.

6.1.7 REFERENCES

1. Arnzen, H.E. "Failure Mode and Effect Analysis: A Powerful Engineering Tool for Component and System Optimization," Fifth Reliability and Maintainability Conference, N.Y., N.Y., sponsored by American Institute of Aeronautics and Astronautics, July 18-20, 1966.
2. Haasl, D.F., W.E. Vesely and N.H. Roberts, "System Safety and Reliability Analysis," University of Washington course material, June 1976.

3. "Fault Tree Analysis: A Technique for Product Safety Evaluation,"
F.A. Scerbo and J.J. Pritchard, ASME 75-SAF-3, presented at the
Engineering Applications Conference, Baltimore, Maryland, May 18-21,
1975, The American Society of Mechanical Engineers, Technical
Division.
4. Hassl, D.F., W.E. Vesely and N.H. Roberts, "Fault Tree Analysis,"
Nuclear Regulatory Commission Technical Report; in preparation.

6.2 Pertinent Military Specifications

6.2.1 FOR ELECTRICAL CONNECTORS

MIL-C-5015.....Connector, electrical, AN type

MIL-C-26482.....Connector, electrical, circular miniature,
quick disconnect

MIL-C-26500.....Connectors, general purpose, electrical
miniature, circular environmental re-
sisting 200°C ambient temperature

MIL-C-27599.....Connector, electrical, miniature, quick
disconnect (for weapons systems) estab-
lished reliability

MIL-C-38999.....Connectors, electrical, miniature, quick
disconnect, removable crimp type contacts,
established reliability

MIL-C-81511.....Connector, electric, circular, high density,
quick disconnect, environment resisting

MIL-C-22992.....Connectors, electrical, waterproof, quick
disconnect, heavy duty type

MIL-C-83723.....Connector, electric, circular, environment
resisting, general specification for

MIL-C-39012.....Connectors, coaxial, radio frequency,
general specification for

MIL-C-24231.....Plugs, receptacle, cable assemblies, and
hull penetrations, pressure proof, 4000 SBM,
general specification for

MIL-C-22249.....Connector sets, electrical, hermetically sealed, submarine

MIL-C-22539.....Connector sets, electrical, hermetically sealed, submarine

MIL-C-24217.....Connector sets, electrical, deep submergence, submarine

6.2.2 FOR ELECTRICAL CABLES

MIL-C-915.....Cable, cord, and wire, electrical shipboard use

MIL-C-23020.....Cable, coaxial, for submarine use

MIL-C-22929.....Cable, electrical, underwater, seadrone lighting

MIL-C-23812.....Cable, electronic, tow, for submarine application

MIL-C-2194.....Cables, power, electrical, reduced diameter type, Naval Shipboard

MIL-C-17.....Cables, radio frequency, coaxial, dual coaxial, twin conductor, and twin lead

MIL-C-24145.....Cable, electrical, special purpose, for shipboard use

MIL-C-13777.....Cable, special purpose, electrical; general specifications for

6.2.3 FOR CONNECTOR MATERIALS

MIL-M-14.....Molding, plastics, and molded plastic parts, thermosetting

QQ-A-591.....Aluminum alloy die castings

QQ-A-225.....Aluminum alloy bar, rod and wire

QQ-A-367.....Aluminum alloy forging

QQ-S-571.....Solder, tin alloy; lead-tin alloy; and lead alloy

QQ-S-763.....Steel bars, shapes and forgings--corrosion resisting

MIL-P-19833.....Plastic molding material and plastic molded parts, gloss fiber filled diallyl phthalate resin

QQ-C-530.....Copper-beryllium alloy bar, rod, and wire (copper alloy No. 172)

QQ-P-330.....Phosphor bronze bar, plates, rods, sheets, etc.

ZZ-R-765.....Rubber, silicone: low and high temperature and tear resistant

QQ-N-286.....Nickel-copper-aluminum alloy, wrought (K-Monel)

MIL-R-6855.....Rubber; synthetic, sheet molded, and extruded, for aircraft applications

QQ-B-679.....Bronze, aluminum, rod, flat products with finished edges (flat wire, strip, and bar) shapes and forgings

QQ-N-281.....Nickel-copper-alloy, bar, plate, rod, sheet, strip wire, forgings, and structural and special shaped sections

MIL-M-24041.....Molding and potting compound, chemically cured, polyurethane (polyethes-based)

QQ-B-637.....Brass, Monel, rod, wire, shapes, etc.

MIL-P-17091.....Polyamide (nylon) plastic rigid: molded parts, rods and flats

MIL-T-9047.....Titanium and titanium alloy bars, forgings, and forging stock

MIL-B-24059.....Bronze, nickel aluminum, rod, flat products with finished edges, shapes and forgings

6.2.4 U.S. GOVERNMENT PLATING SPECIFICATIONS

MIL-G-45204.....Gold

MIL-C-14550.....Copper

QQ-S-365.....Silver

MIL-T-10727.....Tin

QQ-Z-325.....Zinc

MIL-R-46085.....Rhodium
 QQ-C-320.....Chromium
 MIL-A-8625.....Aluminum (anodized)
 QQ-P-416.....Cadmium
 QQ-N-290.....Nickel
 MIL-C-26074.....Nickel (electroless)
 QQ-P-35 and
 MIL-S-5002Stainless steel (passivated)
 MIL-T-10727.....Tin-lead
 MIL-C-13924.....Stainless steel (oxidized)
 MIL-F-495.....Copper (black oxidized)

6.2.5 CONNECTOR TEST SPECIFICATIONS

MIL-STD-202.....Test methods for electronic and electrical
 component parts
 MIL-STD-1344.....Test methods for electrical connectors
 MIL-STD-454.....Standard general requirements for electronic
 equipment
 FED-STD-406.....Methods of testing plastics
 FED TEST METHOD 151....Metal test method
 MIL-C-45662.....Calibration: system requirement
 MIL-STD-10.....Surface roughness, waviness, and lay
 L-P-406.....Plastics, organic, general specification,
 test methods
 FED TEST METHOD 601....Rubber, sampling and testing
 MIL-STD-167.....Mechanical vibrations of shipboard equipment
 MIL-S-901.....Shock tests, H.I. (high impact) shipboard
 machinery equipment and systems, require-
 ments for
 MIL-STD-271.....Nondestructive testing requirements for
 metals
 MIL-STD-810.....Environmental test methods

6.3 Bibliographies on Connector Technology and Related Subjects

6.3.1 CONNECTOR DESIGN

Aamodt, T., Seals for Electrical Equipment Under Water Pressure and Fusion of Marlex to Polyethylene by a Molding Process, Bell Telephone Laboratories, Report No. 56-131-41, August 16, 1956.

Aamodt, T., Seals for Ocean Bottom Equipment Containers, Bell Telephone Laboratories, Report No. MM-61-213-26, February 28, 1961.

Abo, J.M., Splicing Caged Armor Coaxial Cable, Report No. 973, Naval Torpedo Station, Keyport, Washington, April 1969.

Austin, R.S., Exploring Autec Depths with Alvin, Technical Report, Naval Underwater Weapons Research and Engineering Station, Newport, Rhode Island, March 1968, DDS No. AD-389-101L.

Bridges, R.M., "Structural Requirements of Undersea Electrical Cable Terminations," presented at Marine Technology Society Conference, 1971.

Bridges, R.M., "Undersea Cable System Design for the Eniwetok BMILS Installation," presented at Marine Technology Society Conference, Washington, D.C., June 29 to July 1, 1970.

Briggs, E.M. et al., A Wet and Dry Deep Submergence Electrical Power Transmission System, Final Report, Southwest Research Institute, Project No. 03-25707-01, July 25, 1969.

Briggs, E.M., "The Design of a 4160 Volt Deep Sea Wet and Dry Connector System," presented at Marine Technology Society Conference, Washington, D.C., June 29 to July 1, 1970.

Czul, E.C. et al., "Load-Carrying Terminals for Armored Electric Cables," Naval Research Laboratory, Washington, D.C., Report No. NRL-6261, August 31, 1965, NTIS No. AD-621-564.

Dowd, J.K., Design Report--Cable Seal for PQM Hydrophone, General Dynamics, Electric Boat Division, Report No. U411-61-091, July 1, 1961.

Dowd, J.K., Design Study Report--Pressure Proof Hermetically Sealed Coaxial Radio Frequency Hull Fittings for Submarines, General Dynamics, Electric Boat Division, Report No. U413-62-095, Contract NObs 86068, June 1962.

Dowd, J.K. and H.C. Miner, Design Study Report--Watertight Deep Submergence Cable Hull Penetrations Fittings for Submarines, General Dynamics, Electric Boat Division, Report No. U413-62-097, Contract NObs 86-68, June 1962.

Dowd, J.K., Pressure Proof Electrical Cable Hull Penetration Fittings for Submarines, General Dynamics, Electric Boat Division, Report No. SPD-60-101, pp. 60-192, Contract NObs 77007, October 31, 1960.

Edwards, F.L. and R.A. Patterson, "Pressure Balanced Electrical Hull Penetrators and External Cabling for Deepstar 20,000," presented at Marine Technology Society Conference, Washington, D.C., June 29 to July 1, 1970.

Eller, S.A. et al., "Protective Ring for Electronic Cable," Progress Report, Naval Applied Science Laboratory, Brooklyn, New York, DDS No. AD-862-011L.

Field, N.H., "A Reliable Gland for Rubber Cables," Admiralty Research Laboratory, Teddington, England, April 1969, DDC No. AD-857-371.

Forbes, R.J. and N.A. DeLucia, Handbook of Electric Cable Technology for Deep Ocean Applications, Naval Ship Research and Development Center (A), 6-54, November 1970, NTIS No. AD-877-774.

Funk, C.J. et al., Handbook of Underwater Imaging Systems Design, NUC TP 303, July 1972, NITS No. AD-904-472 (L).

Glowacz, A. and J. Louzader, "Thru Hull Electrical Penetrators," presented at Marine Technology Society Conference, 1970.

Hackman, D.J. and B.R. Lower, Summary Report on a Study to Decrease Wire Breakage in Underwater Electrical Connectors, Battelle Memorial Institute, Columbus Laboratories, April 30, 1968.

Haigh, K.R., "Deep-Sea Cable-Gland System for Underwater Vehicles and Oceanographic Equipment," Proceedings, IEEE, Volume 115, No. 1, January 1968.

Handbook of Electrical and Electronic Circuit--Interrupting and Protective Devices for Deep Ocean Applications, Naval Ship Research and Development Center (A), 6-167, November 1971, NTIS No. AD-889-929.

Handbook of Fluid-Filled, Depth/Pressure Compensating Systems for Deep Ocean Applications, Naval Ship Research and Development Center (A), 27-8, April 1972, NTIS No. AD-894-795.

Handbook of Fluids and Lubricants for Deep Ocean Applications, Naval Ship Research and Development Center (A), MATLAB 360, Revised 1972, NTIS No. AD-893-990.

Handbook of Pressure-Proof Electrical Harness and Termination Technology for Deep Ocean Applications, October 1974, NTIS No. Not Assigned.

Haworth, R.F., Aluminaut Electrical Hull Fittings and Outboard Cable Connectors, January 1966.

- Haworth, R.F., Design Study Report: Hermetically Sealed Polaris Umbilical Cable Connectors, General Dynamics, Electric Boat Division, Report No. SPD-60-107, pp. 60-182, Contract NObs 77007 and 4204, November 1960.
- Haworth, R.F., Design Study Report: Watertight Hermetically Sealed Electrical Connectors for Submarines, General Dynamics, Electric Boat Division, Report No. SPD 60-101, pp. 60-194, Contract NObs 77007, October 31, 1960.
- Haworth, R.F., "Electrical Cabling System for the STAR III Vehicle," ASME Paper No. 66-WA/UNT-11, ASME Conference, November 27 to December 1, 1966.
- Haworth, R.F. and J.J. Redding, Design Study Report: Pressure Proof Hull Fitting and DSS-3 Type Cables on AN/BQQ-1 Sonar Array, SSN597, General Dynamics, Electric Boat Division, pp. 59-134, Contract NObs 77007, October 23, 1959.
- Haworth, R.F. et al., Final Report--Phase 1 Review, Design, Fabrication and Test Program for Deep Submergence Electrical Connectors and Penetrators, General Dynamics, Electric Boat Division, Report No. C413-70-016, 3 volumes, May 1970 (Confidential).
- Haworth, R.F. et al., Handbook of Vehicle Electrical Penetrators, Connectors, and Harnesses for Deep Ocean Applications, July 1971, NTIS No. AD-888-281.
- Haworth, R.F. "Packaging Underwater Electrical/Electronic Components on Deep Submergence Vehicles," Insulation/Circuits, December 1970.
- Haworth, R.F. and J.E. Regan, "Watertight Electrical Cable Penetrations for Submersibles--Past and Present", ASME Paper No. 65-WA/UNT-12, ASME Conference, November 7-11, 1965.
- Haworth, R.F. and J.E. Regan, "Watertight Electrical Connectors for Undersea Vehicles and Components," ASME Paper No. 64-WA/UNT-10, ASME Conference, November 29 to December 4, 1964.
- Johnson, E., "Hermetic Seals in Plastic Bodied Connectors," presented at 16th Annual Wire and Cable Symposium, Atlantic City, New Jersey, November 29 to December 1, 1967.
- Kitchin, D.W. and O.S. Pratt, "Jointing Polyethylene-insulated Submarine Cables," IEEE Transactions, Volume 78, Pt. IIIA, 1959.
- Klonaris, O., "Underwater Connectors," Underwater Science and Technology Journal, June 1970.
- Lenk, J.D. and H.B. Sams, Applications Handbook for Electrical Connectors, Bobbs-Merrill Company, Indianapolis, Indiana, 1966.

Lenkey, J., III and W.W. Wyatt, "Polyethylene Bonding to Metal for Cable Penetration of Pressure Hulls and Communications Applications," presented at 17th Annual Wire and Cable Symposium, Atlantic City, New Jersey, December 4-6, 1968.

McCartney, J.F. and J.V. Wilson, "Development of an Underwater Matable High-Power Cable Connector," Offshore Technology Conference, Paper No. OTC 1976, June 1974.

McCartney, J.F. and J.V. Wilson, "High Power Transmission Cables and Connectors for Undersea Vehicles," presented at Marine Technology Society Conference, 1971.

Miaschi, B., "A Cable Gland for Deep-Sea Operation," Saclant ASW Research Centre, La Spezia, Italy, January 1975, AD-A004-842.

Miner, H.C., Design Study Report--Ballast Tank Bulkhead Cable Seals, General Dynamics, Electric Boat Division, Report No. SPD 60-105, pp. 60-195, Contract NObs 77007, October 31, 1960.

Miner, H.C., Final Report--Investigation, Design Development, and Testing of Shore Power Connector Fittings for Permanent Installation in Submarine Hulls, General Dynamics, Electric Boat Division, Report No. U413-66-049, Contract NObs 90521, March 31, 1966.

Morrison, J.B., "An Investigation of Cable Seals," Applied Physics Laboratory, University of Washington, March 1, 1954.

Morrison, J.B., "O-rings and Interference Seals for Static Applications," Machine Design, February 7, 1957.

Nation, R.D., Deep Submergence Cables, Connectors and Penetrators, Nortronics Division of Northrup Corporation (DSSP Contract N00024-68-C-0217), February 21, 1967.

Nelson, A.L., "Deep Sea Electrical Connectors and Feed-Through Insulators for Packaging Electronics," presented at Material Electronic Packaging and Production Conference, Long Beach, California, June 9, 1965.

O'Brien, D.G., "Application of Glass-Hermetic-Sealed Watertight Electrical Connectors," presented at Marine Technology Society Conference, June 1967.

Okleshen, E.J., "Underwater Electronic Packaging," Electrical Design News, Electronic Circuit Packaging Symposium, Fort Wayne, Indiana, August 1960.

Rotary Shaft-Seal Handbook for Pressure Equalized, Deep Ocean Equipment, Naval Ship Research and Development Center (A), 7-573, October 1971, NTIS No. AD-889-330 (L).

Sanford, H.L., Design Study Report--Phase Two--Electrical Bulkhead Connectors for Submarine Holding Bulkheads, General Dynamics, Electric Boat Division, Report No. U413-67-202, December 29, 1967.

Sanford, H.L., Phase I Design Study Report--Electrical Bulkhead Connectors for Submarine Holding Bulkheads, General Dynamics, Electric Boat Division, Report No. U413-66-056, Contract NObs 92442, March 31, 1966.

Sanford, H.L., Design Study Report--Watertight Electrical Plugs for Polaris Missile Harnesses on Submarines, General Dynamics, Electric Boat Division, Report No. 413-62-096.

Sanford, H.L. and R.A. Cameron, Design Study Report--Molded DSS-3 Cable Splices for External Use on Submarines, General Dynamics, Electric Boat Division, Report No. 413-62-211, December 12, 1962.

Sanford, H.L., et al., Final Report--Watertight Deep Submergence Electrical Connectors and Hull Fitting for Submarines, General Dynamics, Electric Boat Division, Report No. 413-65-185, Contract NObs 88518, October 1965.

Saunders, W., "Pressure-Compensated Cables," presented at Marine Technology Society Conference, 1972.

Small, F.B. and R.T. Weaver, "Underwater Disconnectable Connector," presented at Marine Technology Society Conference, 1971.

Smith, O.D., "Connector Design Considerations for Hydrospace Environments," Oceanology International, November 1970.

Spadone, D.M., Meeting on Cables, Connectors and Penetrators for Deep Sea Vehicles, Deep Submergence Systems Project Office, Bethesda, Maryland, January 15-16, 1969.

Spadone, D., et al., "Three Hull Electrical Penetrators for the Deep Submergence Rescue Vehicle," presented at 5th Annual Marine Technology Society Conference, Miami Beach, Florida, June 15-18, 1969.

Thym, G.C. and R.A. Swan, "Underwater Cable Connectors and Terminators for the Hydrostatic Pressures to 10,000 psi," presented at Tenth Annual Wire and Cable Symposium, Asbury Park, New Jersey, November 1961.

Tuttle, J.D., "Underwater Electrical Integrity," presented at Marine Technology Society Conference, 1971.

Walsh, D.K., "Underwater Electrical Cables and Connectors Engineered as a Single Component," presented at Marine Technology Society Conference, June 1966.

White, C.M. and D.F. Denny, The Sealing Mechanism of Flexible Packings, Ministry of Supply, Scientific and Technical Memorandum No. 3/47, H.M. Stationery Office, London, 1948.

White, J.F., Cables and Cable Connectors, NUSL Report No. 1060, Navy Underwater Sound Laboratory, New London, Connecticut, May 13-14, 1969 (Confidential).

Wilson, J.V., "General Technology Review of Electrical/Electromechanical Cable Connections in Ocean Systems," USN Civil Engineering Laboratory, Port Hueneme, California, December 1973.

Wilson, J.V., "Recommended Revision of the 'Handbook of Vehicle Electrical Penetrators, Connectors and Harnesses for Deep Ocean Applications,'" USN Civil Engineering Laboratory, Port Hueneme, California, September 1973.

Wilson, J.V., "Underwater Mateable Electromechanical Connectors for Power and Signal Cables," Offshore Technology Conference, Paper No. OTC 2581, June 1976.

Wilson, J.V., "Wet Connectors at CEL," USN Civil Engineering Laboratory, Port Hueneme, California, July 1975.

Wolski, B., NR-1 Special Test for Effect of Short Circuit Fault Current on Hull Fittings, General Dynamics, Electric Boat Division, Report No. 418-69-001, January 15, 1969.

Wolski, B., NR-1 Special Test for Outboard Electrical Plug/Cable Assemblies and Junction Boxes, Two Volumes, General Dynamics, Electric Boat Division, Report No. 418-69-002, April 25, 1969.

Wolski, B., NR-1 Special Test for Electrical Hull Fittings, Junction Boxes and Associated Cable Assemblies, Two Volumes, General Dynamics, Electric Boat Division, Report No. 418-68-010, October 22, 1968.

6.3.2 SEAL DESIGN

Adiletta, J.D., "How to Apply O-rings," Product Engineering, August 1957.

Bridgman, P.E., The Physics of High Pressure, McMillan Company, New York, 1931.

Carlotta, E.L., "Materials for O-ring Seals--Their Properties and Selection," Materials and Methods, December 1953.

Brown, W., "Environmental Protection With Hermetic Sealing," Electrical Manufacturing, November 1957.

Comer, J., "Glass-to-Metal Seals," Electrical Manufacturing, March 1958.

Dalton, R.H., "How to Design Glass-to-Metal Joints," Product Engineering, April 26, 1965.

Debbi, H., "How to Make Glass-to-Metal Seals. Part I--Matched Seals," Insulation, June 1968.

Debbi, H., "How to Make Glass-to-Metal Seals. Part II--Mismatched Seals," Insulation, July 1968.

Forster, G.A., Hermetic Sealing Terminals, Technical Report 56-251, April 1956, DDC AD-107-274.

Freeman, A.R., "Gaskets for High Pressure Vessels," ASME Paper No. 52-11RD-5, Seventh National Instrument Conference, Cleveland, Ohio, September 9-10, 1952; also printed in Mechanical Engineering, December 1952.

Gasket Design Manual, Armstrong Cork Company, Lancaster, Pennsylvania, 1956.

"Glass and Ceramic Sealing Alloy Tubing," Electromechanical Design, November 1965.

Haworth, R.F., Gasket Study for Outboard Electrical System Enclosures, General Dynamics, Electric Boat Division, Report SPD-57-002, February 14, 1957.

Kutzer, L.G., "Joining Ceramics and Glass to Metals," Material in Design Engineering, January 1965.

McCuiston, T.J. and R.E. Allen, "Factors Influencing O-ring Operation," Applied Hydraulics, June 1950.

MIL-HDBK-212, "Gasket Materials (Nonmetallic)," September 26, 1958.

NAVSHIPS 250-248, "O-ring Service Manual," September 1951.

"Seals Reference Issue," Machine Design, June 11, 1964.

Smoley, E.M., "Design Criteria for Sealing Gasketed Joints," Machine Design, November 21, 1963.

Stasch, A., Handbook on Hermetic Sealing, Amphenol Connector Division, Amphenol-Borg Electronics Corporation, Report No. 5-4, December 5, 1959.

Stasch, A., "The Hermetically Sealed Connector and Its Capabilities," Electronic Industries, May 1964.

Thomson, J.L., "Packed Glands for High Pressure," Product Engineering, November 20, 1958.

Todd, G.F., "Cable Jackets and Water Permeability," AIEE Transactions, Paper No. 61-240, February 17, 1961.

Vroom, W.J. and R.F. Westover, "Classification of Polymers by Their Response to Hydrostatic Pressures," presented at 27th Annual Technical Conference, Society of Plastics Engineers, 1969.

Warring, R.H., Seals and Packings, Trade and Technical Press, Ltd., Norden, Surrey, England, 1967.

Warfield, R.W., "Compressibility of Linear Polymers," Journal of Applied Chemistry, Volume 17, September 1967.

Warfield, R.W., "Compressibility of Bulk Polymers," Naval Ordnance Laboratory, White Oak, Silver Spring, Maryland, Polymer Engineering and Science, pp. 176-180, April 1966.

Warfield, R.W., The Compressibility of Crosslinked Polymers, Naval Ordnance Laboratory, White Oak, Silver Spring, Maryland, NOL TR 64-243, April 1965.

Warfield, R.W., "The Compressibility of Polymers to 20,000 Atmospheres," Naval Ordnance Laboratory, White Oak, Silver Spring, Maryland, ASTIA AD 635-121, June 1, 1966.

Warfield, R.W., J.E. Cuevas and R. Barnat, "Single Specimen Determination of Young's and Bulk Moduli," Journal of Applied Polymer Science, Volume 12, pp. 1147-1149 (1968).

Whalen, J.J. "How to Select the Right Gasket Materials," Product Engineering, October 3, 1960.

Zeitlin, A., "Equipment for Ultrahigh Pressures," Mechanical Engineering, October 1961.

6.3.3 CORROSION AND ENVIRONMENT

Brown, B.F., "Corrosion" in Handbook of Ocean and Underwater Engineering, ed., J.J. Meyers, McGraw-Hill, New York, 1969.

Brown, B.F., Corrosion in the Marine Environment, Publications of the Marine Technology Society, MTS 6th Annual Conference, pp. 1225-1231, June 24-July 1, 1970.

Brown, B.F. and R.J. Goode, "Evaluating Mechanical and Corrosion Suitability of Materials," ASME Paper No. 67-DE-7, ASME Conference, May 15-18, 1967.

"Corrosion and Corrosion Protection of Metals," MIL-HDBK-721 (MR) Military Standardization Handbook, November 1, 1965.

Crouch, W.P., Structural Response of Identical Glass-Reinforced Plastic Pressure Hull Models to External Hydrostatic and Short-Term and Long-Term Cyclic Pressure Loadings (An Interim Report), Structural Mechanics Laboratory, December 1967, Report 2560, Naval Ship Engineering Center, ASTIA AD 829-435.

- Dehart, R.C., "Materials for Marine Use," in Handbook of Ocean and Undersea Engineering, ed., J.J. Meyers, McGraw-Hill, New York, 1969.
- DSSP Instruction 9020.2, Guidelines for Corrosion Control, U.S. Navy Deep Submergence Systems Project Office, PMS-11/201/SH; PM of December 31, 1968.
- Glowacki, A.S., Protective Coatings for Filament-Wound Deep Submergence Vessels, Final Report, U.S. Rubber Company Research Center, Wayne, New Jersey, September 1966.
- Harper Corrosion Guide, The H.M. Harper Company, Molton Grove, Illinois.
- Hunt, J.R. and M.D. Bellware, Ocean Engineering Hardware Requires Copper-Nickel Alloys, International Nickel Company.
- Jerome, R. and J.L. March, Designers Guidelines for Selection and Use of Metallic Materials in Sea Water Applications, General Dynamics, Electric Boat Division, December 8, 1966.
- Laminates and Elastomers Under Deep Submergence Exposure, USN Applied Science Laboratory, Brooklyn, New York, ASTIA AD 412-980.
- LaQue, F.L., Marine Corrosion Causes and Prevention, Wiley and Sons, New York, 1975.
- LaQue, F.L. and H.H. Capson, Corrosion Resistance of Metals and Alloys, Reinhold Publishing Corporation, New York, 1963.
- Leboritz, A., "The Permeability and Swelling Elastomers and Plastics at High Hydrostatic Pressures," Ocean Engineering, Volume 1, Pergamon Press, 1968.
- "Marine Materials," Nickel Topics, Volume 23, No. 3, International Nickel Company.
- Muraoka, J.S., Deep-Ocean Biodeterioration of Materials: Part III, Three Years at 5300 Ft.; Part V, Two Years at 5640 Ft.; Part VI, One Year at 2370 Ft., USN Civil Engineering Laboratory, Port Heuneme, California, 1966-1967, ASTIA AD 631-078, 642-838, and 651-124.
- Muraoka, J.S., "The Effects of Fouling by Deep-Ocean Marine Organisms," Undersea Technology, May 1963.
- Muraoka, J.S., "Effects of Marine Organisms," Machine Design, January 18, 1968.
- Reinhart, F.M., "Corrosion of Materials in Hydrospace: Part I, Irons, Steels, Cast Irons, and Steel Products," USN Civil Engineering Laboratory, Port Hueneme, California, Technical Note N-900, July 1967.

Reinhart, F.M., "Corrosion of Materials in Hydrospace: Part II, Nickel Alloys," USN Civil Engineering Laboratory, Port Hueneme, California, Technical Note N-915, August 1967.

Reinhart, F.M., "Corrosion of Materials in Hydrospace: Part III, Titanium and Titanium Alloys," USN Civil Engineering Laboratory, Port Hueneme, California, Technical Memorandum N-921, September 1967.

Reinhart, F.M., "Corrosion of Materials in Hydrospace: Part IV, Copper and Copper Alloys," USN Civil Engineering Laboratory, Port Hueneme, California, Technical Note N-961, April 1968.

Reinhart, F.M., "Deep Ocean Corrosion," Geo-Marine Technology, September 1965.

A Sample Test Exposure in Shallow Water to Examine Effects of Ocean Environments on Underwater Equipment, TM No. 333, USN Underwater Ordnance Station, Newport, Rhode Island, October 1964, ASTIA AD 450-220.

Sample Test Exposures to Examine Corrosion and Fouling Effects on Materials in the Deep Ocean, TN No. 359, USN Underwater Ordnance Station, Newport, Rhode Island, ASTIA AD 477273.

Saroyan, J.R., "Protective Coatings," Machine Design, January 18, 1968.

Tuthill, A.H. and C.M. Schillmuller, Guidelines for Selection of Marine Materials, The International Nickel Company, New York, 1966.

Uhlig, H.H., The Corrosion Handbook, John Wiley and Sons, New York, 1948.

Webber, A., "Mini-Connector Evaluation," Massachusetts Institute of Technology, June 1967, AD-827-249L.

Woodland, B.T., "Deep Submergence Metal Structures," Machine Design, January 18, 1968.

6.3.4 POTTING COMPOUNDS

Athey, R.J., "Water Resistance of Liquid Urethane Vulcanizates," E.I. DuPont, Elastomer Chemicals Department, Bulletin No. 5, April 1965.

Bandel, D., "Potting and Encapsulating Materials and Methods," Circuits Manufacturing, March, April, June, and July 1969.

Bolger, J.C., "Selection of Connector Potting Compounds," presented at 2nd Annual Connector Symposium, Cherry Hill, New Jersey, October 21-22, 1969.

Ehrlich, A. and J.W. Hayes, "Thermal and Hydrolytic Stability of Urethane Resins," presented at 9th Electrical Insulation Conference (EIC), Boston, Massachusetts, September 8-11, 1969.

Gahimer, F.H. and F.W. Nieske, "Navy Investigates Reversion Phenomena of Two Elastomers," Insulation, August 1968.

Gahimer, F.H. and F.W. Nieske, Hydrolytic Stability of Polyurethane and Polyacrylate Elastomers in Humid Environments, Naval Avionics Facility, Report No. TR-1372, February 27, 1969.

Gahimer, F.H. and F.W. Nieske, Properties of Commercial Polyurethane Rubber Encapsulating Compounds, Naval Avionics Facility, Report No. TR-1032, October 15, 1967.

Gahimer, F.H. and F.W. Nieske, Reversion of Polyurethane and Polyacrylate Rubber Encapsulating Compounds in Humid Environments and Development of a Standard Reversion Test, Naval Avionics Facility, Report No. TR-1201, April 15, 1968.

Griffin, W.R., Reconstitution of Reverted Polyurethane Potting Compounds, Air Force Materials Laboratory, Report No. TR-68-398, April 1969.

Keith, R.E., Potting Electronic Modules, National Aeronautics Space Administration, Report No. SP-5077, 1969.

Koved, F.L. "Encapsulating to Military Specifications," Electronic Industries, July 1963.

Lebovits, A., "The permeability and Swelling of Elastomers and Plastics at High Hydrostatic Pressures," Ocean Engineering, Volume 1, Pergamon Press, 1968.

Leute, F.A., "Urethanes Made Stable at Elevated Temperature and Humidity," Insulation, August 1968.

Redding, J.J., Utilization of Heat Shrinkable Back-shells Over Hydrolytically Unstable Polyurethane Potted Connectors, SSBN634, General Dynamics, Electric Boat Division, Report No. U413-70-019, March 1970.

Rosato, D.V. and R.T. Schwartz, Environmental Effects on Polymeric Materials, Volume I, pp. 1167-1177, Interscience Publishers, 1968.

Schollenberger, C.S., "Polyurethane Chemistry and Environmental Resistance," B.F. Goodrich Company Research Center, Brecksville, Ohio, January 14, 1970.

Turner, J.F., Restoration of Ships Inertial Navigation System Cable, Naval Air Development Center, Report No. NADC-MA-6952, November 14, 1969.

Welch, B.L., "Estimating Service Life of Potting Compound EC2273 Using Accelerated Hydrolytic Reversion at High Temperature and High Humidity," Weber State College, Ogden, Utah, January 30, 1970.

6.3.5 INSULATION MATERIALS

Athey, R.J., "Water Resistance of Liquid Urethane Vulcanizates," Adiprene Bulletin No. 5, E.I. DuPont de Nemours and Company, Inc., Wilmington, Delaware.

Barnett, R.L. and A. Humpreys, "Design for Minimum Weight," Materials in Design Engineering, January 1962.

Beach, N.E., "Government Specifications and Standards for Plastics, Covering Defense Engineering Materials and Applications" (Revised), Picatinny Arsenal, Dover, New Jersey, AD-640-377.

Couzens, E.G. and V.E. Yarsley, Plastics in the Modern World, Penguin Books, Baltimore, Maryland, 1968.

Craig, C.L., "Electrical Properties of Plastics--What They Mean to the Designer," Plastics Design and Processing, February 1962.

Davis, J.W. et al., "The Fatigue Resistance of Reinforced Plastics," Materials in Design Engineering, December 1964.

"Development of Specification for Polyurethane Rubber Used to Encapsulate Submarine Antennas," Mare Island Naval Shipyard, Identification No. 2269-1, August 11, 1964.

DOT Electrical Insulation Material Handbook, U.S. Naval Research and Development Laboratory, Annapolis, Maryland, Report No. 6-166.

Harper, C.A., "Electrical Insulating Materials," Machine Design, September 28, 1967.

Harper, C.A., Handbook of Materials and Processes for Electronics, McGraw-Hill, New York, 1970.

Harper, C.A., "Insulating Materials," Electronic Design, June 7, 1969.

Harper, C.A., Plastics for Electronics, Kiver Publications, Inc., West Adams Street, Chicago, Illinois.

Hauck, J.E., "Engineer's Guide to Plastics," Materials in Design Engineering, February 1967.

Hauck, J.E., "How Water Affects Plastics," Materials in Design Engineering, November 1966.

Insulation Directory/Encyclopedia, Lake Publishing Company, Libertyville, Illinois, June/July 1970.

King, S.B., Materials Bonding, Debell and Richardson, Inc., Enfield, Connecticut, April 1975, AD-A009-098.

Lee, H.J., Oceanographic Effects on Plastic Engineering Materials, US Naval Air Engineering Center, Philadelphia, Pennsylvania, Report NAEC-AML-2536, 1966, ASTIA AD-647-054.

MIL-HDBK-149, "Rubber and Rubber-Like Materials," June 30, 1965.

MIL-HDBK-700 (MR), "Plastics," November 1, 1965.

Morris, L., "Organic Materials in Hydrospace Applications," Products Research Company, February 26, 1964.

Moses, G.L., Electrical Insulation--Its Application to Shipboard Electrical Equipment, McGraw-Hill, New York, 1951.

6.3.6. ADHESIVES

Burtzlaf, H.R. and K.F. Charter, "Factors in Joint Design Using Adhesives for Metal Bonding."

Delay, L.J. "Testing Methods to Evaluate Adhesive Performance," ASME Publication No. 66-MD-46.

Halsey, G.H., "A Status Report of Ultrasonic Inspection Methods for Rubber Bond Condition," ASME Publication No. 68-WA/RP-5.

LaFlamme, P.M., Adhesive Manual and Glossary of Adhesive Terms, Quantum, Inc., Wallingford, Connecticut, 1959.

Malootian, M.H., The Effect of Water Immersion of Some Tensile-Sheer Bonds, Naval Underwater Sound Laboratory, Technical Memorandum No. 2220-124-67, June 1967.

Marriott, J.A., Development of Adhesives for Salt Water Use, General Dynamics, Electric Boat Division, Report No. U413-63-168, December 31, 1963.

MIL-STD-454, Requirement 23, "Adhesives," January 5, 1965.

MIL-HDBK-691 "Adhesives."

Patrick, R.L., "Factors Determining the Strength of Adhesive Bonds," ASME Publication No. 70-DE-33.

Pattee, H.E., "Adhesive Bonding of Titanium," Materials in Design Engineering, February 1959.

Peters, H., "Bonding Polyethylene to Rubbers, Brass, and Brass Plated Metals," Bell Telephone Laboratories, October 15, 1957.

Rider, D.K., "Which Adhesive for Bonded Metal Assembly," Product Engineering, May 25, 1964.

Rider, D.K., "Surface Preparation for Bonded Metal Assembly," Product Engineering, June 8, 1964.

Rauhut, H.W., "Pretreating Polyethylene for Optimum Structural-Adhesive Joints--Theoretical Concepts, and Surface Pretreatments," Adhesive Age, December 1969 and January 1970.

Sharpe, L.H., H. Schonhorn and C.L. Lynch, "Adhesives," International Science and Technology, April 1964.

Snogren, R.C., "Optimal Selection of Adhesives Related to Performance Needs," ASME Publication No. 70-DE-69.

Snogren, R.C., "Surface Treatment of Joints for Structural Adhesive Bonding," ASME Publication No. 66-MD-39.

Stokes, E.P., "Adhesives for the Electrical/Electronic Industry," Insulation/Circuits, September 1970.

6.3.7 QUALITY CONTROL

Arnzen, H.E., "Failure Mode and Effect Analysis: A Powerful Engineering Tool for Component and System Optimization," presented at Fifth Reliability and Maintainability Conference, New York, Sponsored by American Institute of Aeronautics and Astronautics, July 18-20, 1966.

Development of Specification for Polyurethane Rubber Used to Encapsulate Submarine Antennas, USN, Mare Island Rubber Laboratory, Vallejo, California, Report No. 11-8, August 11, 1964, ASTIA AD-441-158.

Material Certification Procedures and Criteria Manual for Manned Noncombatant Submersibles, NAVSHIPS Manual 0900-028-2010, Naval Ship Systems Command, Department of the Navy, Washington, D.C., September 1, 1968.

Molding and Inspection Procedures for Fabricating Connector Plugs for Submarine Outboard Cables, NAVSHIPS 0962-022-2010, Naval Ship Engineering Center, Hyattsville, Maryland.

Oberg, E. and F.D. Jones, Machinery's Handbook, 18th Edition, Industrial Press, New York, 1959.

Reliability and Maintainability Handbook, NAVSHIPS 0900-002-3000, Chapter 12: "Failure Modes and Effects Analysis."

Roark, R.J., Formulas for Stress and Strain, 3rd Edition, McGraw-Hill, New York, 1954.

Safety and Operational Guidelines for Undersea Vehicles, Marine Technology Society, Undersea Vehicle Committee, Washington, D.C., 1968.

"Seals and Seal Testing Procedure (for Electronic Enclosures)," US Air Force, MIL-S-8484, June 25, 1964.

Seely, F.B., Resistance of Materials, 3rd Edition, John Wiley and Sons, London, 1954.

Shigley, J.E., Machine Design, McGraw-Hill, New York, 1956.

Spadone, D.M., Meeting on Cables, Connectors, and Penetrators for Deep Sea Vehicles, U.S. Navy Deep Submergence Systems Project Office (DSSP), Bethesda, Maryland, January 15-16, 1969.

Technical Manual--Installation Practices for Aircraft Electric and Electronic Wiring, NAVWEPS 01-1A-505, July 1, 1965.

Wiring, Molding, Testing Installation, Maintenance and Repair Procedures for Watertight Electrical Submarine Connectors and Penetrators, NAVSHIPS Dwg NR-1-302-2663185, Naval Ship Engineering Center, Hyattsville, Maryland.